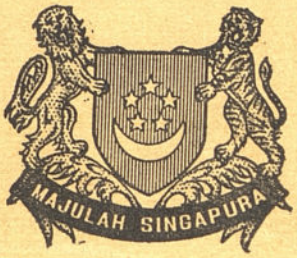

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No. 34, March 1966

Observations on the Fauna of Pulau Tioman and Pulau Tulai

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CONTENTS

GLOSSARY OF MALAY LANGUAGE TERMS

Belukar	=	Regenerating vegetation, thick brush to secondary forest
Bukit (Bt.)	=	Hill
Gunong (G)	=	Mountain
Kampong (Kg.)	=	Village
Ladang	=	Ricefields on dry ground or hillsides
Pulau (P.)	=	Island
Sungei (S.)	=	River
Tanjong (Tg.)	=	Cape, or headland
Telok (Tk.)	=	Bay
Ulu	=	Headwaters and catchment area (of a stream)

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1. General Introduction

By J. A. BULLOCK

and

LORD MEDWAY

INTRODUCTION

PULAU TIOMAN is the third largest island off the shores of Malaya; only P. Langkawi and P. Pinang (Penang) exceed it in area and these are more closely related to the mainland than is Tioman. Several visits have been made to the island by zoologists, although some of these have not been reported in the literature. In all reported cases, the visits have been of short duration. Vertebratologists have been mainly concerned with the collection of museum specimens, principally of the higher classes, and have made little or no attempt to assess the populations of species or their role in the ecology. The invertebrates have received little attention, with the exception of the Rhopalocera (Corbett and Pendlebury, 1956; Stubbs, 1961) and the terrestrial Planaria (de Beauchamp, 1933). Medical workers have, however, accumulated much data, largely unpublished, on the anopheline vectors of malaria and on the incidence of plasmodial infections in the human populace (Warren, this *Bulletin*, p. 150).

In March to April, 1962, a party from the Department of Zoology, University of Malaya, spent six weeks on the island. The aims of this expedition were to undertake a study of the vertebrate fauna in relation to the ecology of the island, and to make a collection of insects and other terrestrial arthropods paying special attention to the fauna of jungle habitats and to the ectoparasites of vertebrates. Besides the authors, the party consisted of two technicians from the Department of Zoology, an insect-collector employed by the Bishop Museum, Honolulu, and an aborigine servant. This basic party was visited for short periods by several other groups: O. S. Elliot and D. R. Wells, both of the Department of Zoology, spent two weeks on the island; a group from the Institute for Medical Research, Kuala Lumpur, consisting of F. L. Dunn, B. L. Lim, and McW. Warren, with three assistants, stayed for a week; and two plant collectors from the Botanic Gardens, Singapore, spent three weeks with us.

DESCRIPTION OF THE ISLAND

P. Tioman lies some 24 miles, at the nearest point, off the east coast of Malaya (fig. 1) between longitudes 104° 7′ to 104° 15′ E. and latitudes 2° 44′ to 2° 54′ N. It is a pear-shaped island with the main bulk of land in the south (Plate 1), 14 miles long on a north-south axis and some seven miles broad at its widest east to west. It has an area in plan of about 44 square miles (fig. 2). In general, the profile rises steeply from the shore, although areas of flat land of up to quarter of a mile or more in extent back the larger bays on the east and west coasts. On the west coast, bays are separated by precipitous headlands, and on the east much of the coast-line is cliff (Plate 1). In the southern portion of the island the land rises to over three thousand feet in three places, as ridges which have a mainly east-west orientation. At the extreme south, Kg. Mokut is dominated by the twin stacks

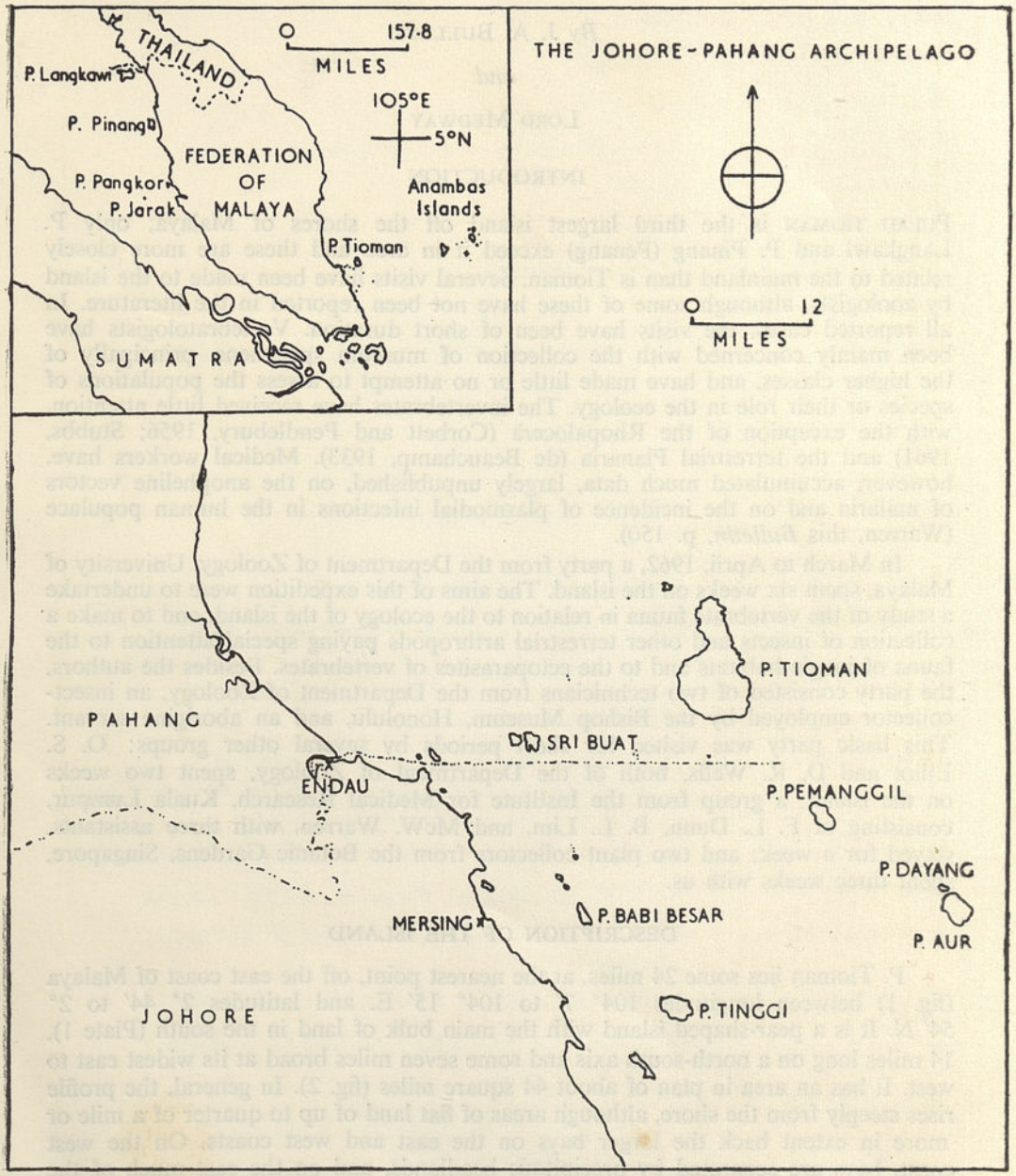

Figure 1. The Johore-Pahang Archipelago, showing its relation to the mainland.

Figure 2. Sketch map of Pulau Tioman, showing principal localities mentioned in the text. Sites of expeditionary camps are indicated by arabic numerals.

of Nenek Si-Mokut (Plate 2) the sides of which are too steep to carry forest vegetation. In the northern portion the terrain attains less altitude and apparently consists of a single, very broken ridge with a north-south orientation.

Geologically, the island is included in the Sunda shelf. The greatest sounding between Tioman and the Malayan mainland is 22 fathoms, at a point close to the island. Hence, unless the land is of very recent upraising, it must periodically have been connected to the Malayan mainland during the major recessions of the sea that occurred at intervals in the Pleistocene.

According to Alexander (1962), it is inferred that the island lies along an anticlinal axis which extends in a NNW direction to include the east coast of mainland Malaya (State of Trengganu). On the west side of Tioman, all exposed rocks are granitic. Towards the east side, there is a transition to rocks of a volcanic series, and in places this is clearly marked by changes in the vegetation which may be associated with drainage or with subsoil fertility (Mitchell, see below). A striking feature everywhere, which has been commented on by several authors, is the many large boulders exposed on the surface (Plate 2), between which caves, sinks, and pot-holes often run into the hillsides.

The climate is dominated by the north-east monsoon which blows from November to March, producing a wetter season in these months than during the rest of the year. However, rain is frequent even in other months, especially on high ground where precipitation appears to be greater than on the coast[1]. The islanders state that the fruiting of orchard trees (notably durian) in Juara and Tekek is often not synchronised[2], indicating variations in local climate within the island.

Drainage is provided by many small rivers and streams, which are permanent only at lower altitudes. On the hillsides, drainage is very rapid and above 2,000 ft. surface streams are ephemeral and running water can only be found underground. No river attains any size and forest streams are generally swift-flowing, following a boulder strewn course with many short falls and slides (Plate 3). In the flat coastal areas, the typical river course changes to a meander. The water flows quickly into the sea at low tide, but at high tide backs-up and partially floods the flat area. All rivers are obstructed at the mouth by shallow sand bars, so that even local boats of 3 ft. draught can only enter at high tide. In some cases, the bar has caused a change and considerable shift of the river mouth so that the final reach is parallel to the shore (Plate 3). In other cases, the stream has been totally obstructed, so that the water accumulates in ponds and only reaches the sea by percolating through the intervening sand dunes. In these conditions areas of fresh-water swamp have arisen in several places, but regions of permanent brackish swamp are limited.

INHABITANTS

There is evidence that, with few interruptions, the island has been inhabited for at least the past millenium by a fluctuating human population which has rarely exceeded one thousand (but see Warren, this *Bulletin*, p. 155). At the time of our visit, the permanent population numbered about 1,100 people, nearly all of whom were Malay or Indonesian in origin and almost exclusively Muslim in religion. Permanent habitation is confined to the coast. The majority of people live on the west side of the island in scattered villages centred around Kg. Tekek which is nowadays the administrative headquarters[3], possessing the only jetty, police station

1. No exact meteorological data are available.

2. In 1961–62, Juara durians reached peak bearing some 8 weeks later than those at Tekek.

3. The Penghulu (resident administrative officer of the island) moved to Tekek from Juara in 1953.

and dispensary. The rest of the population live in the neighbourhood of Kg. Juara on the east coast and Kg. Mokut in the south. Kg. Mokut is largely inhabited by families originating from Telok Nipah, traditionally the oldest settlement on the island, which is now deserted although there is abundant evidence of past occupancy (Medway, 1962).

Coconuts yield the main cash crop and all suitable land around and behind the villages has been planted. At Tekek and Juara, the flat subcoastal areas carry stands of old, tall palms beneath which considerable scrub growth is present (Plate 4). At Mokut there is little flat subcoastal area, and the palms, which are mainly young, have been planted on the lower slopes up to c. 250 ft. above sea level. At higher levels, hill rice and tapioca (*Manihot utilissima*) are planted everywhere on cleared land (ladang cultivation) up to 250–300 ft. above sea level. It has lately become the practice for these crops to be succeeded by plantings of banana, followed in turn by coconut. No rubber has been planted on P. Tioman to date.

Rice and tapioca form the carbohydrate staples. In addition some islanders keep chickens, cattle and goats, and all further supplement their protein requirements by catching fish. However, fishing is not practised commercially, except during the monsoon months when there is an influx of medium-sized fishing craft based on the mainland which find shelter in the lee of the island. A few islanders earn additional money by collecting jungle produce and edible birds' nests for sale in Mersing.

Communications between the island and the mainland (ordinarily Mersing) are limited to visits by fishing and trading vessels, and there is no regular passenger boat service. A VHF wireless station is operated by the police at Tekek. On the island, Tekek and Juara are linked by a rough track which has obviously been in use for many years but is only suitable for human traffic since no pack animal or vehicle could negotiate the steep and rocky path. Mokut is not linked overland with either of the other villages and all normal communication is by boat[4].

ECOLOGICAL BACKGROUND

The only published account of the botany of the island is that of Henderson (1930) who confined his study to a report of the species found and their altitudinal distribution. The island has however been visited on a number of occasions by officers of the Forest Department. We are indebted to Mr. B. A. Mitchell of the Forest Research Institute, Kepong, for abstracting the relevant data from the field notes of these officers, as well as for supplying us with his own impressions and notes on the island resulting from a trip made there in May 1962. We have drawn heavily on these notes in compiling the following account.

The flat coastal areas have been completely cleared of primary vegetation except in one or two places (principally at Kg. Tekek and Tk. Nipah) where brackish swamp has been colonised by mangrove. Coconut has been planted throughout the area and beneath this a heavy weed growth, dominated by *Lantana* sp., has sprung up in many places (Plate 4); but where regular clearing has been practised, only a short grass layer is found. Seaward, a narrow band of typical shore flora retains a precarious hold, with such plants as *Casuarina*, *Euphorbia heterophylla* and *Canavalia*, the sea-bean. Behind the coconut plantations, as mentioned, there is a zone of shifting cultivation consisting of cleared patches of the current year's rice, denser stands of tapioca, fresh plantations of banana (Plate 5) or coconut seedlings, stands of regenerating scrub of varying

4. A recent press report (*Straits Times*, July 21, 1964) stated that, since our visit, an airstrip had been built at Kg. Tekek and that a road linking Tekek and Juara was under construction.

height and density (in which *Lantana* sp. dominates), irregular patches of secondary forest (belukar) at all stages of growth from young and impenetrable to mature, tall, and relatively open.

Elsewhere, forest covers the whole island, extending down to the sea except in the cleared areas. Inland, there is little evidence of cultivation in the past. Along the Juara-Tekek track there is some land, since reverted to jungle, which was cleared during the time of the Japanese occupation. There is also a tradition, supported by the presence of old durian trees some two miles from the shore, that at Tk. Nipah, during the existence of the settlement, cultivation extended well inland. In the Tk. Paya area too Mr. Mitchell found regeneration apparently dating from Japanese times. In all the recently cleared areas, the first stage of regeneration is marked by the presence of heavy *Lantana* growth.

The primary forest consists of tall, well spaced trees with a fairly open canopy and few emergents. The number of dipterocarp species is very limited. Undergrowth of all sorts is sparse on the west side but appears to be rather more dense on the east. Both Henderson (loc. cit.) and Mitchell attributed the overall sparsity to excessively good drainage due to the presence of granite boulders; but whilst Henderson related the denser growth in the east to higher rainfall, Mitchell considered that it is the result of the change from granitic to volcanic series.

A number of timber species have been reported by foresters, mainly in the south, and in this century a few abortive attempts have been made to extract *Dipterocarpus* spp. (mainly *D. grandiflorus* which is also tapped for resin) and *Shorea curtisii*. Successful exploitation was hampered by the steep and rocky terrain, and the forest has been little affected. A certain amount of minor felling of timber for boat-building and repairs has undoubtedly taken place, and there is a report of logs of *Hunteria corymbosa* being exported in 1936. It is nonetheless evident that the composition of the main inland forest has been changed but little by human interference.

Below 1,500 ft., there is a shrub layer of rattans and palms (predominantly bertam, *Eugeissona tristis*, and kabong, *Arenga* sp.), and in open areas, especially along the Tekek-Juara track, a considerable carpet layer is present (Plate 5). Above 1,500 ft., the dominant shrub layer plant is the small palm *Licuala* sp., and, in most places, including Ulu Lalang (Camp V, 3,080 ft.), this type of forest continues fairly evenly to the summit. However on G. Kajang, at 3,406 ft. the highest peak of the island, a vegetational succession is evident in the upper 600 ft. From 2,800 ft. the forest is dominated by a bamboo (*Schizotachyum gracile*) which constitutes up to half of a hill dipterocarp forest standing about 30 ft. tall. Above 3,150 ft. this is succeeded by elfin forest occupying the long, gently sloping, penultimate ridge in a zone covering about 100 ft. in altitude. The dominant trees of this zone are *Baekia fructescens*, *Leptospermum flavescens* and *Tetracomia* sp., all of which are 12–20 ft. high, gnarled and flat-topped (Plate 6). These small trees are widely spaced, and a considerable carpet layer exists, including grasses, a sedge (*Scleria* sp.), small palms, ferns (*Dipteris conjugata* and *Gleichenia microphylla* var. *semioestita*), pitcher plants (*Nepenthes* sp.), *Lycopodium* sp. and orchids. Succeeding this zone, the slopes of the final rise to the summit from about 3,250 ft. carry a low forest of slender, crowded trees about 25 ft. tall which are covered at the bases of the trunks with mosses and liverworts. There is no carpet layer, but a thin understorey of rattans and *Licuala* is present (Plate 6). The last 15 ft. and the summit proper are covered by an extremely dense secondary growth resulting from recent[5] clearing for survey purposes, and containing many plants including the ferns *Histiopteris incisa* and *Gleichenia linearis*, standing up to 10 ft. tall.

5. From the evidence of scratched initials and dates on the survey beacon, we assume the date to have been 1958.

The basic ecology of the island therefore conforms to the normal ecological zonation described by Richards (1957). Above the zone of cleared land, there is a Tropical Rain Forest stratum gradually transforming to a Submontane Rain Forest with the lower limit of the latter possibly indicated by the appearance of *Licuala* sp. at 1,500 ft. and its upper limit (on G. Kajang) by the bamboo-dominated forest reaching to 3,150 ft. Above this one there is a short zone of Montane Rain Forest. It is characteristic of island floras that this compressed succession occurs at much lower altitudes than in the main Malayan ranges (*Massenerhebung* effect).

PULAU TULAI

Pulau Tulai (Plate 7), which is the only island of any size in close proximity to P. Tioman, lies to the north-west at a distance of some three miles from the nearest point of the main island. It is irregular in shape, achieving a length of one mile on the east-west axis and with a three-quarter mile peninsula projecting somewhat west of north. It has an area of about one square mile. The general character of the island is much the same as P. Tioman. Much of the coast line is rocky, but there is a fairly large bay on the northwest side bordered in part by sandy shores and supporting about an acre of mangrove; there are also smaller bays on the east side (Plate 7). Extensive coral reefs occur in the mouth of the principal bay, making a close approach impossible except by one channel. There is a sandy coastal flat behind this bay, beyond which the land rises steeply to a ridge running the length of the island at a varying height up to 300 ft. and descending in only one place to under 100 ft. There is no permanent fresh-water and only one brackish well. The island has been cropped for coconut by people from Tioman, who used to visit P. Tulai intermittently for a few weeks at a time, but there is no record of permanent human settlement.

Floristically, P. Tulai is considerably depleted. In the past, all suitable land has been cleared for the planting of coconut palms. Aged palms now form the dominant vegetation on much of the island, but there has been great regenerative growth which is already as tall as the palms in many places. Some of the larger forest trees were left during the clearing operations, and these are now interspersed by similar secondary growth which often attains considerable size but has not reached its climax.

ITINERARY

A base camp was established at the rest-house on the beach at Kg. Tekek (Camp I, in fig. 2) which offered water-proof storage for our equipment, and was retained by us throughout the trip (Plate 8). A hut (Camp II) was built at c. 1,000 ft. in tall primary forest at the highest point on the track between Tekek and Juara. This camp was occupied by the entire basic party from the fifth to twelfth day, whilst individual members of the expedition and visitors used it repeatedly throughout our stay (Plate 8). From the sixteenth to eighteenth day, the party visited P. Tulai, occupying a shelter (Camp III) built by the copra collectors on the western beach behind the mangrove; this trip was repeated during the sixth week (38th–40th days). The whole of the fourth week was taken up with a visit to Mokut where an unoccupied house (Camp IV) was rented and used as a base for sorties to the interior of the southern end of the island. In the fifth week, a six-day trip was made to G. Kajang (3,406 ft.) A camp (Camp V) was established in a cave on the adjacent ridge to the north (3,080 ft.) because accessible water could not be found on Kajang itself. The two authors also spent one night on the summit of Kajang (Camp VI) in order to make late evening and dawn observations. No camp was established at Juara, since the area was easily reached from Camp II, although most members spent at least one night there during the trip.

ACKNOWLEDGEMENTS

The running costs of the expedition were met by a grant of US. $1,000 from the Bernice P. Bishop Museum, Honolulu.

We are indebted to the District Officer, Mersing, and Chief Police Officer, Mersing, and to their staff for considerable assistance given to us in our preparations and during our trip.

Professor J. R. Hendrickson, and the Institute for Medical Research, Kuala Lumpur, made unpublished notes and reports available to us for study prior to our departure whilst Mr. B. A. Mitchell aided us greatly with his report on the botany of the island. Identifications of several of the plants collected were kindly made available to us by the Director of the Botanic Gardens, Singapore.

The District Officer, Rompin, gave permission for our use of the rest-house, and provided us with the necessary information. The Federal Survey Department kindly gave information used in the preparation of this report. Our boatman, Inche Osman bin Haji Ali, of Mersing, provided a reliable link with the mainland and performed many jobs for us which were outside his contract. Many people on the island helped us, and to all we are grateful, especially to the Government Officers, as well as to our guide on several trips, Inche Ismail bin Haji Ali.

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2. The Mammals

By LORD MEDWAY

INTRODUCTION

SEVERAL EARLIER zoological expeditions interested in mammals have visited Tioman, but dates and personnel have been mentioned only *en passant* in scattered accounts of the animals collected. Visits which failed to produce publishable taxonomic results may have gone unrecorded. A survey of the literature discovers mention of the following: 1899, Dr. W. L. Abbott with C. B. Kloss (Miller, 1900, 1903, Kloss, 1908); 1906, H. C. Robinson (Thomas, 1908); 1907, H. C. Robinson and E. Siemund (Kloss, 1908); 1912, H. C. Robinson and E. Siemund (Robinson, 1912); 1915, H. C. Robinson (Robinson, 1917); 1916, C. B. Kloss (Chasen, 1940).

As a result of their efforts, twenty-seven species of mammals were recorded from Tioman, of which seventeen, a very high proportion, had been described as endemic subspecies. No formal list of the mammals of the island has previously been published, although most records were mentioned by Chasen (1940).

During our visit we failed to find four of the mammals previously reported from Tioman (two bats, the Slow Loris, and the Shrew-faced Ground Squirrel); we were unable to collect one (the Hairless Bat); and we refrained from collecting another (the Long-tailed Macaque). On the other hand we succeeded in collecting five species not hitherto recorded (three bats, a flying-squirrel and a rat[6]) bringing the total number of land mammals known from Tioman to thirty-one. Stories from the islanders suggest that another civet may remain uncollected. It is also possible that further bats exist undetected. With these exceptions, it is unlikely that future expeditions will add significantly to the list.

No mammals have hitherto been recorded from P. Tulai.

In the following pages all the mammals known from these islands are discussed, and the habitat that each occupies is outlined. Unless otherwise indicated, all measurments are given in mm. Our observations of the food of the specimens that we collected, and of the reproductive condition of females, are given in some detail. The taxonomic position of the Tioman population of each species is also examined as far as material permits. Where they exist, accepted English names are given together with the colloquial equivalents current on Tioman, which in several cases appear to be unique to the island dialect.

All permanent specimens have been deposited in the collections of the Department of Zoology, University of Malaya.

ACKNOWLEDGEMENTS

I am grateful to Mr. J. A. Bullock for identifying arthropod material from the stomach contents discussed below, to B. L. Lim for making available certain specimens and other data collected by the I.M.R. team during their visit to Tioman, and to Professor J. L. Harrison of the University of Singapore for making available the unpublished data appearing as Table 8.

6. These new records are marked with an asterisk in the list below.

ANNOTATED LIST

PULAU TIOMAN

Hylomys suillus tionis Chasen. Lesser Gymnure, ? *Salak ba'a*.

We trapped only an adult male and a subadult female of the Lesser Gymnure, both on the ground in the bamboo forest near the summit of G. Kajang. On two occasions, single animals, active by day, were also seen on the slopes just below Camp V. We did not record the species below 2,700 feet. On Tioman, as throughout its present range, it appears to be common only on high ground above about this altitude.

One animal came to a bait of cooked fresh meat, the other to coconut, but in both cases the stomach was empty when examined and the bait had not obviously been eaten.

The occurrence of a normally montane terrestrial mammal on Tioman is of some interest. It should be noted that the Juara villager who offered the curious name *Salak ba'a* (which was not recognised in other villages, where nobody could be found who had seen *Hylomys* alive) claimed that the animal also occurs at much lower altitudes. Whether or not this is true, the recent discovery (Medway, 1964) of a mandible of *Hylomys* in a archaeological deposit little above sea-level at Niah, Sarawak, at a depth corresponding to a C^{14} date of c.39,000 B.C., indicates that in the late Upper Pleistocene the habitat of this mammal extended to the lowlands[7]. This important archaeological discovery (the specimen was recognised by the Earl of Cranbrook) demonstrates that, at a period when a lowered sea-level had either joined Tioman to the Sunda land-mass or at least had considerably diminished the intervening sea barrier, *Hylomys* occurred in the lowlands, and would thus have had an increased opportunity to colonise the island either directly overland or by rafting.

Based on two skins collected in 1915 and 1916, Chasen (1940) separated the Tioman population from *maxi* Sody of mainland Malaya and of Sumatra by the following characters: Upperparts "very slightly more richly coloured, the difference being especially noticeable on the posterior half of the back, and on the outside of the thighs. Prevailing colour of the underparts buffy, not grey. Skull very slightly longer than in the available specimens and records of *maxi*".

For comparison with our single adult skin (evidently the third from Tioman) I have two recently collected skins from Kg. Janda Baik, on the Selangor-Pahang border. On the latter (*maxi*) the upperparts are indeed very slightly darker and less fulvous than on the former (*tionis*), due to somewhat greater prominence of the black guard hairs. The underparts are indistinguishable; in both cases the hairs are grey for most of their length, distally tipped buff[8]. The length of the skull of *tionis* (greatest length 37.8 mm., cf. 37.9 for the type) fractionally exceeds the longest skull of *maxi* (greatest length 37.1 mm.). In all other measurements there is overlap. The Tioman *Hylomys* is thus marginally distinct from the mainland population, and on the present specimens retention of the subspecific name can be justified.

7. The greatest depression of sea-level during the last glaciation was within 100 m. (330 feet) (Zeuner, 1959) and cannot have significantly affected the present altitudinal boundaries.

8. Chasen's description of *tionis* was based on only two skins, 25 years old, which may well have lost colour.

Crocidura malayana tionis Kloss. Malayan White-toothed Shrew, *Tikus pahit*.

We obtained two males and three females of this small shrew. One was taken from a cat in a house on the hillside above Juara. The other four were trapped by Longworth small mammal traps in a variety of sheltered habitats: tall coconut plantation just behind the beach, scrub and grass (not *Imperata*), tall secondary forest without undergrowth, and primary forest near Camp II. We failed to trap or see this shrew on the high ground around Camp V, or on G. Kajang, and it probably does not range to these altitudes.

Trapping figures are analysed in Table 1, and show on overall catch of just under 4 per 100 trap nights. This rate indicates that the shrew must be very much commoner in Tioman as a whole (including unproductive habitats) than in any comparable tract of forest on the mainland, where to date in over 400 trap nights in forest habitats I have caught only one *Crocidura* in the Longworth trap.

TABLE 1

Mammals caught in the Longworth small mammal trap

Habitat	No. of trap nights	*Crocidura*	*Rattus tiomanicus*	*Rattus exulans*
Foreshore	4	0	0	1
Coconut plantation ...	11	1	0	0
Harvested *ladang*	10	0	1 (juv.)	0
Lowland scrub and grass ...	20	1	0	0
Tall secondary forest ...	4	1	0	0
Primary forest at 1,000 ft. ...	24	1	0	0
Primary forest over 2,500 ft. ...	30	0	0	0
Total ...	103	4	1	1

As *tikus pahit*, the shrew was familar to the islanders, several of whom asserted that it often enters houses. This claim was supported by our catch of one male taken from a cat in a house and, since *Suncus* the usual commensal shrew is absent, it may well be true.

All stomachs were empty; one contained traces of unidentifiable insect food.

One out of three females was pregnant, with a single foetus in the right uterine horn.

The Tioman shrew belongs to the group of middle-sized, close-furred and moderately long-tailed *Crocidura* of South-east Asia, of which *C. malayana* is the representative on the Malayan mainland. The Tioman form was originally described as a separate species, based on a series of five specimens collected in 1915 (Kloss, 1917). But these specimens were not apparently compared with shrews from the mainland and, on doing so, I can find no characters warranting specific separation.

I have before me a good series of *C. malayana* collected by the Institute for Medical Research, Kuala Lumpur, including seventeen taken from one restricted area (Bukit Lagong Forest Reserve, Selangor). As shown in Table 2, which gives the principal flesh measurements, there is considerable overlap, although the ten from Tioman are on average slightly smaller, with slightly longer tails than the mainland series. Statistically, the difference does not warrant separation of the two populations, which are equally indistinguishable by skull characters and by texture and length (3 mm. mid-dorsum) of the fur. Since the mainland series were all preserved in spirit it is not possible to compare the fur colour of the two forms.

A single freshly collected skin of *malayana* is however available in the Zoology Department collection. The Tioman skins are all consistently very slightly browner in overall colouration than the mainland skin. The form *tionis* was described as being comparatively brown (Kloss, 1917) and until further material is available this character may be taken to distinguish the island race.

TABLE 2

Principal flesh measurements of *Crocidura* from Tioman and the Malayan mainland.

Locality	No. of Specimens	Head and Body *Range*	Head and Body *Mean*	Tails as % of H and B *Range*	Tails as % of H and B *Mean*
Bt. Lagong F.R., Selangor ...	17	75–95	86.8	67–77	71.9
P. Tioman	10	70–92	82.2	69–83	76.8

Cynocephalus variegatus taylori (Thomas). Flying Lemur, *Kujul.*

Not rare. Recorded from coconut gardens (by night) once at Tekek and once at Mokut, and once from primary forest at about 2,600 ft. in the pass between Camp V and G. Kajang (by day).

An adult female was collected on 4th April, carrying an unweaned juvenile male (head and body 263 mm., weight 372 gm.), and also pregnant with one male foetus (head and body c.45 mm., weight with maternal reproductive tract 33 gm.) in the left uterine horn.

The Tioman flying lemur is distinguished subspecifically from geographically neighbouring forms, including the distinct race on nearby Pulau Aor, by the proportionately large size of its teeth, particularly the anterior teeth. Measurements in mm. of the adult female, collected 4th April, 1962 (with those of the type, a subadult male, in parentheses) are as follows: Head and body 398 (338); tail 255 (179); hind foot 69 (49); ear 21 (16). Skull: condylobasal length 71.4 (66); zygomatic breadth 46.8 (42.3); interorbital breadth 20.6 (17); upper toothrow 36.4 (35); length of anterior maxillary tooth 6.8 (7.1), of second maxillary tooth 5.9 (5.8), and of the four molariform teeth 14.8 (15).

Pteropus hypomelanus lepidus Miller. Island Flying Fox, *Kluang.*

There are two large roosts of this bat, permanent according to reports, in coconut palms on the foreshore, one just south of Tanjong Mesoh, Tekek, and the other at the east end of Kg. Mokut. Specimens have also been collected in the past at Juara (Hill, 1961), but at that village residents claim no knowledge of a roost nearer than Tekek. At Setegap, near Juara, these bats came to the fruiting durian trees soon after dusk, and fed on the fruit already opened by squirrels. Evidently their feeding range included the whole island.

We collected nine bats from one roost in a coconut tree at Tekek; all were male, suggesting the possibility of segregated roosting.

Pteropus hypomelanus is characteristically restricted to islands. The race *lepidus* is widely distributed, extending from the east coast Malayan islands to the Anamba archipelago.

***Cynopterus brachyotis brachyotis** S. Müller. Malaysian Fruit-bat.

This bat was repeatedly caught by night in mist-nets set in scrub and young plantation at Tekek, in overgrown plantation, belukar and tall forest at Mokut, and in primary forest around Camp II. It did not enter nets set on high ground above 2,500 ft. in the vicinity of Camp V, and is probably restricted to the lowlands, where it is common and widespread.

Seven females from Tulai and Tioman together were kept for specimens. Within this sample reproductive condition varied widely: two females were in advanced pregnancy, one in mid-pregnancy, one had a newly implanted embryo, and three showed no signs of breeding. One conceptus was present per pregnant bat, in either uterine horn.

Three races of *Cynopterus brachyotis* are known from the Malayan mainland (Hill, 1961). Measurements of the forearm (65–68 mm.) and ear (15–19 mm.) of our series of twelve (5♂, 7♀) from Tioman and Tulai, although somewhat larger than average, are within the range of dimensions of the nominate race, which extends from Borneo to the Malayan lowlands as far north (on the west coast) as central Perak; its range on the east coast is uncharted.

***Eonycteris spelaea** Dobson. Cave Fruit-bat.

This bat was also caught in mist-nets in scrub and plantation at Tekek and Mokut, but was not obtained in forest. No roost was located.

One female was trapped; it was pregnant with one foetus in the right uterine horn.

Emballonura monticola monticola Temminck. Sheath-tailed bat.

A female, pregnant with a mid-term foetus in the left uterine horn, was shot over the beach at Tekek (19th March).

Rhinolophus refulgens refulgens Andersen. Horseshoe bat.

We obtained a male from Mokut, and a male from Tekek, both in tall forest on the lower slopes of the hillside. Both on Tioman and elsewhere Rhinolophids and other microchiropterans have successfully been trapped by night in large numbers by means of standing mist-nets set in forest. It is therefore significant that no bats were caught in our mist-nets during 16 net-nights in the vicinity of Camp V. Che Ismail, a professional collector of the edible nests of cave-dwelling swiftlets (see Medway, this *Bulletin*, on Birds, p. 43) knew of no bat roost in any of the numberous caves at higher altitudes that he habitually visited.

This species is distinguishable from the following one by a somewhat shorter forearm, a high triangular (as opposed to rounded) prominence on the connecting process between anterior and posterior nose-leaves, and a dark brown pelage uniformly coloured to the bases of the hairs. Flesh measurements are: Head and body 40, 40; forearm 39, 40; ear 15, 15; weights 4.5 and 5.3 gm. respectively.

Rhinolophus klossi Andersen. Horseshoe bat.

In the type description, this bat was said to occur on both Tioman and Pemanggil. On the other hand Hill (1960), in his account of mammals collected by H. C. Robinson (who visited Tioman repeatedly, as noted above), listed specimens only from the latter island. We did not find it, and its inclusion among the fauna of Tioman may be erroneous.

Rhinolophus affinis superans Andersen. Horseshoe bat.

A male and female were netted in forest at Mokut with *R. refulgens* (above). The female was pregnant with one late foetus.

This bat has previously been recorded from Tioman by Hill (1960). Collector's measurements of the two present specimens are (male and female respectively): Head and body 52, 51; tail 16, 15; forearm 44, 47; ear 21, 20.

***Hipposideros bicolor atrox** Andersen. Roundleaf Horseshoe bat.

A female in advanced pregnancy was taken from an evening flight stream in disturbed forest at Mokut on 7th April. Measurements agree with the mainland Malayan race: Head and body 52, tail 28, forearm 47, ear 17.

Hipposideros larvatus barbensis Miller. Roundleaf Horseshoe bat.

This race of *H. larvatus*, described from St. Barbe Island (=P. Pejantan) between Lingga and Borneo, is recorded from Tioman and Aor by Hill (1960). We did not find it.

Cheiromeles torquatus Horsfield. Hairless bat.

The Hairless Bat is recorded from Tioman in a footnote to Thomas (1908) provided by H. C. R. (obinson). It is the largest microchiropteran in our region, and in flight its action and silhouette are unmistakeable. Small evening flights above the forest canopy were seen originating from points inland of Tekek and about 1 mile south of Juara, but neither roost could be located.

Tupaia glis sordida Miller. Common Treeshrew, *Kenchong*.

As shown by our overall trapping results (cage traps) in Table 3, treeshrews are very abundant on Pulau Tioman. Below 1100 ft. they were trapped in all habitats except the arid foreshore and belukar, but were taken most frequently in undisturbed primary forest. By day we often encountered small parties, usually one to four in number, on the ground or in shrubs or in the lower storeys of the forest. Although conspicuous, they were not noticeably tamer than on the mainland. On the hills above 2,500 ft. no treeshrews entered our traps, and in six days we saw only one animal, this at the lower margin of the zone, near the pass between Camp V and G. Kajang.

Of the many treeshrews obtained, eight (3 ♂, 5 ♀) were retained as specimens. Four stomach contents were examined and contained respectively (sex and habitat in parentheses): (♂, rice stubble) banana (=bait), plus one small beetle; (♀, lower edge of forest) banana (=bait), plus well masticated insect food including two fragmentary orthopteran tegmina (?Gryllidae), two hemelytra of a heteropteran bug, and one beetle (?Chrysomelidae); (♀, lower edge of forest) banana (=bait), one caterpillar, one hind wing of a heteropteran bug; (♂, scrub and grass; shot, not trapped) chiefly a hard-coated, black-seeded fruit, plus one large wing of a heteropteran bug and one slug.

Of five females, only one showed overt signs of breeding: from Tekek, 17th March, pregnant, one foetus in each uterine horn, and mammary glands active.

Many races of *Tupaia glis* have been described from the mainland and islands of Malaya. Most of the latter, including *T. g. sordida* from Tioman, are endemic to single small islands. With the use of a reflectometer, Hill (1960) has shown that in dorsal colouration, the race *sordida* is only very slightly duller than *T. g. ferruginea* from corresponding latitudes on the west coast of the mainland. It can still be distinguished by its darker underparts and very dull, almost obsolescent shoulder flash. Fresh skins of *T. glis* in the collection of the Zoology Department, University of Malaya, from Rompin, Pahang, opposite P. Tioman on the east coast of the mainland, are considerably brighter and redder than skins from the west coast, and are thus even more distinct from the Tioman specimens. The Tioman race is also smaller on average than mainland *ferruginea* although, as our data show, there is overlap in all flesh measurements. Of eight specimens with fully erupted dentition, head and body measure 157–184, tail 134–155, and hind-foot 37–42 mm.

TABLE 3

Mammals caught in baited cage traps.

Habitat	Trapping days	*Rattus tiomanicus*	*Rattus sabanus*	*Rattus surifer*	*Rattus exulans*	*Rattus cremoriventer*	*Callosciurus notatus*	*Callosciurus nigrovittatus*	*Lariscus insignis*	*Hylomys suillus*	*Tupaia glis*	Total	Catch per 100 trap day/nights
Foreshore	10	..	..	..	*	..	..	..	..	..	..	0	0
Coconut plantations ..	30	2	..	..	..	..	..	..	..	..	1	3	10
Rice stubble ..	147	17	2	..	12	..	..	..	..	..	6	37	25
Scrub and bush (*Lantana*)	70	17	..	2	1	2	1	..	..	..	4	27	38.5
Belukar and secondary forest	81	26	7	2	..	..	1	..	..	..	..	36	44.5
Primary forest below 1200 ft.	168	6	8	4	..	..	..	1	1	..	22	42	25
Primary forest over 2500 ft.	202	4	13	24	..	1	..	..	7	2	..	51	25.4
Totals ..	708	72	30	32	13	3	2	1	8	2	33	196	36.2
I.M.R. team trapping figures (all lowland habitats) ..	n.k.	19	3	6	..	1	2	2	2	..	20	55	..

*One *R. exulans* was trapped in a Longworth small mammal trap on the foreshore.

Nycticebus coucang insularis Robinson. Slow Loris.

In 1917, Robinson recorded that the Slow Loris "is apparently rare in Tioman, and is unknown to the majority of the inhabitants". This remained true in 1962. At Tekek and Juara, several villagers asserted that it did not occur on the island. Only at Mokut was it known; there people remembered that a single animal had been caught and kept for some time in 1958. The only published record, the type specimen of the endemic race *insularis*, "was obtained in felling a patch of heavy jungle" at S. Nipah (Robinson, 1917). Thus all available evidence indicates a small population restricted to the southern end of the island.

Macaca fascicularis laeta (Elliot). Long-tailed Macaque, *Kera*.

Only this monkey is found on Tioman. It is common and, according to the islanders, a pest of cultivation. We regularly found a large troupe in tall forest on the Juara side of Camp II. More usually, we saw troupes in fringing forest, near the ricefields at Tekek, not far from the shore at Tk. Nipah, and on the hillsides above Mokut[9].

The populations on P. Tioman and P. Tinggi are described as very brightly coloured, and on this character have been separated from the mainland as a distinct subspecies (see also Hill, 1960).

Ratufa bicolor tiomanensis Miller. Black Giant Squirrel, *Mengkawak*.

This squirrel is common in the upper storeys of the primary forest throughout the length of the Tekek-Juara path. It is noisy and unafraid, usually giving its presence away by its loud alarm call, scolding furiously from the tree tops. At Mokut it was said to be a pest of young coconut trees in plantations on the upper slopes; at Tekek it was seen in the strips of low secondary forest which ran between areas of cleared ladang. On high ground we did not record it, but a skeleton was found in the pass (2,367 ft.) between Camp V and G. Kajang.

The endemic race is distinguished from the mainland from *R. b. peninsulae* Miller by its shorter tail (Thomas, 1907). The distinction is confirmed by our series of three (2 ♂, ♀), the tails of which measured 325–395 mm. (cf. 29 specimens of *peninsulae*, 395–540 mm., in Hill, 1960).

Callosciurus notatus tenuirostris Miller. Plantain Squirrel, *Tupai Kampong*.

Abundant in plantations in all settlements, and a serious pest of coconuts. It also ranges into the scrub and secondary growth at the lower margin of the forest; but, as stomach contents emphasise, in all habitats it depends for food on either plantation crops (principally coconut) or fruits of associated weed plants. Two animals entered our ground traps, but the majority of the specimens collected (6 ♂, 6 ♀) were shot.

Examined stomach contents were as follows: (♀ early pregnancy, in coconut plantation) mostly ripe *Lantana* berries, plus at least 20 large winged ants; (♀ lactating, coconut plantation) mostly coconut flesh, plus a few *Lantana* berries and two or three ants; (♀ early pregnancy, coconut plantation) mostly coconut flesh, plus a few *Lantana* berries and mixed insects comprising a score of small worker ants of two sorts (one red, one black), 3 abdomens (4 mm. long) of large winged ants, 1 caterpillar (c. 8 mm.), 1 thrips (3 mm.), 1 mite, and 1 small parasitic wasp; (♂, coconut plantation) 9 large caterpillars (20 mm.); (♂, lower edge of

9. The anti-malaria team, U.S.P.H.S., (see Warren, this *Bulletin*, on Malaria) shot seven macaques for blood samples, but unfortunately were unable to arrange to keep any of the carcases for permanent preservation.

forest) mostly *Lantana* berries; (♀, lactating, fruiting durian tree) 80% vegetable matter, chiefly durian pulp, plus a hard stone (4 mm. long) of some other fruit and unidentified yellow pulp, the remainder insects including recogniseable fragments of ants and beetles. These stomach contents indicate a mixed diet similar to that taken by *C. notatus* on the mainland (Harrison, 1962).

Of six females, four were lacating without obvious signs of recurring pregnancy (17–26th March), and two (17th, 18th March) were in early pregnancy, both with two foetuses in the left uterine horn only.

The endemic Tioman race is little differentiated from the form on the neighbouring mainland, but may be distinguished by a shorter rostrum, and a proportionately shorter tail (79–92% head and body) which with a very few exceptions lacks the red tip (see Hill, 1960). It is more sharply differentiated from the forms on Pemanggil and Aor, which are markedly smaller.

Callosciurus nigrovittatus microrhynchus Kloss.

Black-banded Squirrel, *Tupai Kampong*.

C. nigrovittatus is not rare, but still is very much less common than *C. notatus*. At Tekek and Juara it was recorded only below 500 ft. in the lower storeys of the forest, extending into coconut plantations alongside *C. notatus*. Both species, with *S. tenuis*, were feeding together in fruiting durian trees at Setegap, Juara, at the end of March. We did not encounter *nigrovittatus* in forest above 500 ft., and failed to record it altogether at Mokut.

Three stomach contents were examined: (♂, in coconut plantation) entirely coconut flesh; (♂, in durian tree) durian pulp, plus one small black ant; (♀, lactating, in durian tree) chiefly durian pulp, plus unidentified yellow pulp, and a high proportion of insect remains, including about six large worker ants (10 mm. long). These data indicate a diet similar to the mixed fruit and insects taken by mainland *nigrovittatus* (Harrison, 1962), and suggest that on Tioman, where the ranges of *C. notatus* and *C. nigrovittatus* overlap, the two species are competing for the same foods.

Of the two females collected, one (26th March) was lactating.

The endemic subspecies on Tioman was originally separated from the north-eastern Malayan form of *C. nigrovittatus* on the basis of relative dimensions of the nasal bones. But Hill (1960) has shown that this character does not distinguish it from *C. n. joherensis* (Robinson & Wroughton) of southern Malaya, from which it can only be separated by a slight difference in the shade of the tail colour. It is also on average somewhat smaller, but the overlap in measurements is too great to warrant separation statistically.

Sundasciurus tenuis tiomanicus (Robinson). Slender Squirrel, *Tupai Chelis*.

Common throughout the tall forest, from the lower margin to Camp V and the summit of G. Kajang. It was usually seen in small parties of four or so animals, foraging in the lower and middle storeys, rarely descending to the ground. It was seen in company with *C. notatus* and *C. nigrovittatus* only in the fruiting durian trees at Setegap.

Harrison (1962) has recorded that the diet of mainland *S. tenuis* consists mostly of fruit, with a comparatively small amount of insects. This was also true of seven Tioman animals examined, all of which (including a lactating female) had taken much less insect food than was common among *C. notatus* and *C. nigrovittatus*: (♂, forest) unidentified vegetable pulp, plus two ants; (♂, forest) stomach more or less empty, no matter identifiable as of animal origin; (♂, forest) as above;

(♀, forest) unidentified fruit and vegetable pulp, plus one large black and yellow banded leg of a big ?spider; (♀ lactating, in durian tree) chiefly durian pulp, plus a seed coat, and a few insect remains; (♂, highland forest) exclusively unidentified vegetable pulp.

Of two females collected, one was lactating (26th March).

The endemic subspecies on Tioman is distinguished from *S. t. tenuis* (Horsfield) of comparable latitudes on the mainland only by the slightly duller, less ruddy colouring of the dorsal surfaces of the hands and feet.

Lariscus insignis fornicatus Robinson.

Three-striped Ground Squirrel, *Tupai Belang*.

This squirrel was found in tall forest only, at all altitudes from the lower margin (150 ft.) of the forest to the higher slopes of G. Kajang. It was common on the relatively level stretch of ground on the Juara side of Camp II (where we did not trap—cf. Table 3), and on the slopes around Camp V; in both places we frequently encountered animals by day, usually singly. One animal, on being released from the trap, instantly ran down a hole in the ground between the roots of the undergrowth.

The villagers at Mokut claimed that this squirrel was a pest of coconut seedlings, attacking the young shoots. We found that, although coming readily to vegetable baits, trapped animals usually ate little if any of the bait. We killed and skinned two adults whose stomach contents were: (♂, highland forest, trapped on banana bait) no obvious bait or vegetable matter, identifiable animal remains consisting of part of the mesothorax of a large muscid, leg and other sclerites of a large beetle, leg and sclerites including the tegmen of a ?blattid; (♀ lactating, lowland forest) banana (=bait), plus some indeterminate vegetable matter and the remains of two beetles. A third specimen killed was a subadult male (17th April) and although it was almost full-grown (head and body 169, tail 98, weight 145 gm.) its stomach contained only milk.

The adult male had large scrotal testes, and the female was lactating (23rd March).

TABLE 4

Dimensions of the nasal bones of *Lariscus insignis*

	Median length of nasals	Greatest breadth of nasals	Length/breadth ratio
L. i. fornicatus			
ad ♂	12.9	6.1	2.11
ad ♀	14.4	6.6	2.18
L. i. jalorensis (Selangor)			
ad ♂	13.8	6.4	2.15
ad ♀	14.6	6.1	2.39

The endemic subspecies *fornicatus* was characterised as: "Differing from other forms of *Lariscus insignis* (Cuv.), in its somewhat slighter skull, the nasals broadening less anteriorly and by having the rostrum decidely more arched laterally, i.e. the nasals meet at an angle instead of lying practically in the same plane" (Robinson, 1917). This description was based on two adults and "two somewhat immature males" (Robinson, *l.c.*), but since juvenile rodents characteristically have shorter, more arched nasal regions than mature adults of the same species,

it is doubtful whether the latter should have been included. In the absence of measurements, which are not given by Robinson, it is hard to compare our specimens. Measurements of the breadth and length of the nasals of the two adults from Tioman, and of two adults from Selangor, show only slight overlap (Table 4), but longer series are desirable before the status of *L. i. fornicatus* can be reassessed with confidence.

Rhinosciurus laticaudatus robinsoni Thomas. Shrew-faced Ground Squirrel.

The type description of the endemic race of this squirrel is based on a series of three collected from the region of Kg. Juara (Thomas, 1908). Four specimens (undated) are listed among the Robinson collected by Hill (1960). But during our stay we neither trapped, nor saw, nor obtained any indication of the presence of this squirrel. Previous reports (Thomas, 1908; Robinson, 1912) do not suggest that this squirrel was rare on the island fifty years ago and our experience suggests that the population has been severely depleted, if not exterminated, within these few decades.

The Tioman race was described as differing markedly from *R. l. tupaioides* Blyth of the Malayan mainland and the Anamba Is., showing affinities with the Bornean *R. l. laticaudatus* (Müller).

Petaurista petaurista melanotus (Gray). Red Giant Flying Squirrel, *Kandau*.

The many typical tree squirrels (*C. notatus, C. nigrovittatus* and *S. tenuis*) that were feeding by day in the fruiting durian trees at Setegap, Juara, retired at dusk and were replaced by this and the following species of flying squirrels, which glided in from neighbouring trees soon after nightfall. Neither group appeared to be roosting in the durians. We did not see flying squirrels elsewhere but they were reported common, and pests of coconut.

Two females were collected, neither pregnant.

The Tioman population cannot be differentiated from the mainland form.

***Iomys horsfieldi** cf. **davisoni** (Thomas).* Horsfield's Flying Squirrel, *Kunsam*.

Although well known to islanders throughout Tioman, this flying squirrel has not previously been recorded from the island in scientific literature. We saw it only in the durians at Setegap, but by report it was widespread.

Two females were collected, neither in breeding condition.

TABLE 5

Collector's measurements of *Iomys horsfieldi* (in mm.)

No.	Sex	Head and Body	Tail	Hind Foot	Ear
T62.49	♂	185	190	33	21
T62.50	♀	190	188	34	23
T62.60	♀	195	172	35	24
*R51.921	♀	165	183	34	24

*Collected and kindly made available by B. L. Lim of the I.M.R.

Only two skins of the mainland race are available, but comparison suggests that the Tioman form may prove to be distinguished by slightly duller, less ruddy underparts. Measurements of those collected by ourselves and by the I.M.R. team are given in Table 5.

Rattus sp. **tiomanicus** (Miller). Tioman Field Rat, *Tikus*.

This rat, with the following (*R. exulans*), is a serious pest of cultivated land on Tioman. It swarms in ladang doing extensive damage to the rice crop, and infests coconut plantations and durian orchards, feeding on fallen fruit already opened by squirrels or porcupines; it also extends to the surrounding scrub and brush, and belukar and secondary forest throughout the lowlands. But it is also common in the primary forest at all altitudes, and its range evidently includes the whole island (Table 3).

Three stomach contents were examined: (♀, pregnant and lactating, coconut plantation) 75% coconut flesh, plus other unidentifiable vegetable matter, and at least four small cyclorrhaphan larvae (4 mm.); (♂, coconut garden) mostly ripe *Lantana* berries; (♂, lower edge of forest) 70% banana (=bait), remainder coconut flesh.

Of nine adult females skinned, seven were lactating (17th March, 16th April, 20–22nd April); of these five were also pregnant. The remaining two females had recently ovulated. An occupied (but apparently unfinished) nest, from which a rat escaped, was found in the hollow in the top of a rotten coconut palm stump, 2 ft. tall, on 10th April. The nest consisted of a rough ball of dry grass blades (*Imperata cylindrica*) and dry broad leaves, having two entrances.

The taxonomic position of this rat is discussed below (Medway and Lim).

Rattus exulans concolor (Blyth). Little Burmese Rat, *Tikus*.

This rat was trapped only in or near houses (including one on the foreshore at Tekek, just outside the rest house), or in the rice stubble. It is abundant to the degree of being a pest within this range (Table 3) but does not occur outside it[10].

Of five adult females collected, all were in active breeding state: of four taken on 19th and 20th March, two were lactating and not obviously pregnant, one was in early pregnancy (four foetuses), and one in late pregnancy (three foetuses); a fifth female collected on 24th April was lactating.

The Tioman population is not distinguishable from *R. e. concolor*, which is widespread on the Malayan mainland and offshore islands, and on islands of the southern and western South China Sea.

Rattus sabanus stridens (Miller). Long-tailed Giant Rat, *Tikus Mundok*.

R. sabanus is common in forest of all type at all altitudes; a few animals were also trapped in the rice stubble at Tekek (Table 3). It was abundant in the primary forest on the stretch of relatively flat ground to the east of Camp II, and we found it unshy and easy to watch by torchlight at night. Here we also excavated several burrows, leading to leaf-filled nest chambers; but none were occupied.

It came readily to all vegetable baits (banana, coconut, and sweet potatoes) and generally ate much if not all the bait in the trap. Three stomach contents were examined: (♂, highland forest) much bait, the bulk of the remainder unidentified vegetable pulp, plus at least 7 small termites; (♀, highland forest) chiefly bait, plus a few insect remains, including ants and termites; (♂, open secondary forest) cheifly bait, plus the remains of several worker termites. The small number of insects taken contrasts with Harrison's report (1962) that in the diet of mainland *R. sabanus* insects are a "major item with vegetable matter".

Only one adult female was killed; this was lactating, and also in early pregnancy (4 foetuses).

10. Hendrickson and Harrison (1961) have stated that *R. exulans* "is the commonest rat on Tioman Island". Locally this may be true, but in most habitats *R. exulans* is absent, and it is certainly not numerically the most abundant rat on the island.

The ground colour of the dorsal pelage of our series from Tioman is slightly richer and redder than that of recently collected specimens of the mainland form *R. s. vociferans* (Miller); the effect is perceptible mainly on the flanks, where the prominent black guard hairs are sparse. The Tioman race also averages somewhat smaller in body measurements with a proportionately shorter tail. But statistical comparison of these measurements on eight adults from Tioman, compared with seven from Selangor and from Rompin, east coast Pahang, shows that the overlap is considerable, and the coefficient of difference (0.608) is below the conventional level of subspecific difference (see Mayr *et al.*, 1953: 145–6).

Rattus surifer binominatus (Kloss). Common Spiny Rat.

This rat was found only in forest or bush, and was not trapped in the rice fields. It occurred at all altitudes, but was relatively more abundant on high ground than at lower levels (Table 3). Near Camp II we again found burrows attributed to this species.

It came to all vegetable baits, but unlike *R. sabanus* often ate very little of the bait in the trap. Eight stomach contents were examined: (♀, juvenile, lower edge of forest) practically all *Lantana* berries; (♀, early pregnancy, lowland forest) some banana (=bait) plus the head of a terrestrial gastropod (a snail or, since no shell was found, probably a slug) and a considerable amount of insect remains including a beetle elytron and several metallic green sclerites of ?muscids; (♀, juvenile, lowland forest) banana (=bait) plus a maggot (5 mm.) and a few unidentified insect sclerites; (♀, recent ovulation, lowland forest) banana (=bait) plus unidentified insect remains; (♂, lowland forest) banana (=bait) plus one ant, and a fair number of unidentified insect sclerites; (♂, highland forest) well masticated insect remains comprising mostly red-brown sclerites, lacking wings, likely to be nymphal orthopterans or blattarians; (♂, highland forest) 25% coconut (=bait), pieces of the hind body of a small snake, plus unidentifiable insect sclerites; (♀, not breeding, highland forest) a little coconut (=bait), part of a gastropod, and insect remains including portions of a beetle; (♂, highland forest) a little coconut (=bait) but mostly unidentifiable insect remains. Harrison (1955a) has already noted that "insect is the most important foodstuff" (sic) in the diet of mainland *R. surifer* and/or *rajah*, but did not record gastropod or vertebrate remains in the stomachs of his samples.

Of five adult females collected, two were in reproductive condition: one (22nd March) pregnant with four early implants in the right horn only, the other (10th April) recently ovulated.

Hill (1960) has discussed the status of the two spiny rats, *R. surifer* and *R. rajah*, and has shown that the endemic forms of Tioman, Pemanggil, and Aor, are correctly ascribed to the species *surifer*. The Tioman population is distinguished from the mainland *R. s. surifer* (Miller) by somewhat darker and duller dorsal coloration, by a tail on average proportionately shorter, and by the reduced crowns of the molars (Kloss, 1908). The reduction of the molars is accompanied by enlargement of the rostrum and other modifications which in rodents characterise adaptation to an insectivorous diet (extreme in *Rhinosciurus*, for instance).

In separating adults of mainland *R. surifer* from *R. rajah pellax* (Miller) the number of scale rings per cm. of the tail at about mid-point, as noted in the original descriptions, has proved a useful character, being 10 or less per cm. in *rajah* and 11 or more in *surifer* (Harrison, 1957: 14). In Tioman *surifer*, however, the number of scale rings in the tails of our of adults varies from 11.5–9.2 per cm. Nonetheless, the absence of any specimen referrable to *rajah* on pelage characteristics supports the contention that the two forms are specifically distinct (cf. Harrison, 1957).

***Rattus cremoriventer** subsp. Pencil-tailed Rat.

Specimens of this rat were trapped in belukar at Tekek and at Mokut, and in bamboo forest on G. Kajang at 2,900 ft. Since it does not freely enter traps set on or near the ground (as most of ours were) these low trapping figures cannot be compared directly with catches of other Tioman rats. Still it does not appear to be common.

The contents of one stomach were examined: (♀, not pregnant, montane bamboo forest) mostly coconut (=bait), plus greenish sclerites of a ?muscid, and a few other insect remains.

One of the two females collected was pregnant, with one early implant in each horn (9th April).

TABLE 6

Measurements of *Rattus cremoriventer* from the Malay Peninsula and from P. Tioman (in mm.)

Measurement	P. Tioman (4 skins)		Malay Peninsula (Hill, 1960)	
	Range	(*Mean*)	*Range*	(*Mean*)
Head and Body ...	147–156	(152)	121–162	(138)
Tail	189–196	(192)	172–216	(190)
Skull:				
Greatest Length	36.6–38.7	(38.0)	n/a	
Condylobasal length	33.7–35.8	(34.7)	30.1–34.4	(31.9)
Zygomatic breadth	16.9–17.5	(17.2)	15.4–17.1	(16.0)
Interorbital breadth	6.3–6.7	(6.4)	5.5–6.3	(5.9)
Maxillary toothrow	6.1–6.4	(6.2)	5.7–6.5	(6.0)

Four specimens were collected by the combined teams. In coloration they are not distinguishable from the mainland race *R. c. cremoriventer* (Miller). However, while the tail again averages proportionately shorter, in other dimensions (particularly of the skull) the Tioman rat is larger. A longer series would probably warrant subsepecific separation (Table 6).

Atherurus macrourus tionis Thomas. Brush-tailed Porcupine, *Landak*.

Porcupines are extraordinarily abundant on Tioman. Everywhere the lowland forest is criss-crossed with porcupine trails, and characteristic heaps of droppings are found in many rock shelters. The animals are active chiefly by night, when many descend to feed in cultivated areas. By night we found large numbers of porcupines under the fruiting durians at Setegap, nosing out the durians as soon as they fell and gnawing immediately through the thorny skin; they were remarkably tame and fearless. In the highland zone we did not encounter porcupines, although a freshly barked tree near the pass below G. Kajang indicated that they do range up to this height.

A large proportion of the population evidently subsists off plantation crops, including fallen coconut and other fruits, and tapioca, but the stomach contents of a female (not pregnant) shot in the forest, contained only other vegetable matter (unidentifiable). Exposed roots, and the bases of trunks up to 18 ins. above ground, of two species of trees, *Erytamia corymbosa* (Apocynaceae) and *Dysoxylum* cf. *flavescens* (Meliaceae), were frequently barked by porcupine. There is evidently plenty of naturally occuring food available in the forest.

Two females were collected, both subadult and not in reproductive condition.

The endemic subspecies on Tioman is separated from the mainland *A. m. macrourus* (Linn.) by its smaller size. A comparative series is not available, but the measurements of our specimens agree well with the type of *A. m. tionis*.

Paradoxurus hermaphroditus milleri Kloss. Palm Civet, *Munsang jebat*.

Reported to be quite common, although we only saw two specimens, one in a coconut palm on the foreshore at Mokut, the second in forest above Tekek at about 700 ft.

The one female collected was subadult.

The subspecies *milleri* is endemic to Tioman. It is distinguished from the mainland form by paler, more bleached coloration overall, with less defined black markings on the dorsum, and by smaller average size. In the type description (based on one adult female examined) a number of distinctive skull characters were also noted separating *milleri* from a single adult male from Kuala Kangsar, Perak, on the mainland. Measurement of a longer series of skulls from the mainland shows that these characters are not constant and do not serve to distinguish the races.

?Arctogalidia trivirgata. Small-toothed Palm Civet, *Munsang akar*.

A number of villagers at Mokut insisted that there were two civets on the island. Their descriptions of the second suggest this species.

Tragulus napu rufulus Miller. Mouse-deer. *Pelandok*.

There is only one species of mouse-deer on Tioman, but it is very abundant. As a basis for comparison with other localities, on a short test walk by night in primary forest along the path leading east from Camp II, eleven animals were encountered in twenty minutes; similar frequencies were commonplace throughout the lowland forest on Tioman, but would be very unusual (if not improbable) anywhere on the mainland. Mouse-deer were also encountered in cultivated land and throughout the forest up to the high ridge by Camp V.

One female was collected, pregnant with a single foetus near parturition.

The race *rufulus* is endemic to Tioman. It is distinguished by its bright coloration and by size, being intermediate between the Larger and Smaller Mouse-deer of the mainland. Chasen (1940) assigned it to the former, now known as *T. napu*, Hill (1960) to the latter (as *T. kanchil* Raffles=*javanicus* Osbeck); I have followed Chasen.

(**Bos** sp. Domestic cattle).

Herds of feral domestic cattle used to occur in several parts of the forest on Tioman. Many have now been rounded up, and the remnants are reported to occur only inland of Telok Dungun on the east coast. These herds have bred freely in the feral state, and the wild-raised calves are said to be unusually fat and fit.

PULAU TULAI

Cynopterus brachyotis Müller.

Several were netted in the low "pass" in the centre of the island. They are unlikely to have crossed from Tioman.

The specimens collected have been discussed above.

Macroglossus lagochilus cf. **lagochilus** Matschie.

A male, indistinguishable from the mainland form, was collected hanging from a palm frond at night.

Rhinolophus sp.

A small colony of a rhinolophine bat was noted, roosting in the interstices between big boulders at the foot of the ridge.

Callosciurus notatus Boddaert.

Only this squirrel occurs on Tulai. It is abundant throughout the island, although villagers at Tekek assert that within human memory, before coconuts were planted, there were no squirrels on Tulai.

Stomach contents: (♀, lactating) mostly coconut flesh, plus pollen, two caterpillars, and unidentified insect sclerites; (♀, lactating) mostly unidentified fruit pulp, with the remains of perhaps two insects.

Three females were collected (3rd April); two were lactating, one pregnant with two foetuses in the left horn. On the same date, two occupied nests were located in the mangrove fronting Camp III, one 25 ft., the second 15 ft. from the ground. The latter was collected. It was a domed sphere, with a single lateral entrance, consisting of cup-shaped foundation of unidentified dry twigs, supporting a roof of strips of the fibrous leaf-sheath of coconut palm, and an inner lining (1½ ins. thick) of the same material, finely shredded. This nest contained a pair of young (head and body 77, 78).

Three adults were collected. They are not distinguishable from the Tioman population.

Rattus cf. **tiomanicus** group.

The Tulai rat is abundant throughout all parts of the island, including the mangrove patch. Animals were active even by day, and a great nuisance in the camp by night. Despite the considerable overcrowding indicated, all animals collected or observed were healthy.

Observations by night indicated that this rat depended largely on a diet of fallen coconuts, damaged by squirrels. The stomach of one female (lactating) shot, contained much coconut flesh, plus the abdomen of one ant.

On April 4th, one female of two collected was lactating; on 23rd April, of four collected, one had recently ovulated, one was lactating, and a third gave birth in the trap (one live young seen, 4.4 gm.).

The taxonomic position of this rat is discussed elsewhere (Medway and Lim).

Rattus exulans Peale.

A male and female were trapped near the abandoned settlement; but this rat was not common.

DISCUSSION

ECOLOGICAL RELATIONS

The number of species of mammals found on Tioman, both generally and in any one habitat is very much fewer than in any comparable tract of land on the mainland. In Table 7 the number of species found in all types of forest on P. Tioman is compared with the number collected from a circumscribed area of lowland and submontane forest in Selangor (Bt. Lagong Forest Reserve) by the Institute for Medical Research, 1948–60 (I.M.R., 1960: 76–77). The mammals collected by the I.M.R. do not include many of the larger forest species, notably gibbons, deer, tapir, rhinoceros and elephant, none of which are present on Tioman. The success of feral cattle on Tioman suggests that under prevailing ecological conditions the island could support a viable population of larger ruminants.

TABLE 7

Collected faunas of the lowland and submontane forest of P. Tioman and Selangor

Family	No. of species collected P. Tioman	Selangor
Erinaceidae	1	2
Soricidae	1	4
Cynocephalidae	1	1
Pteropidae	3	9
Microchiropteran genera	4	14
Tupaiidae	1	3
Lorisidae	1	1
Cercopithecidae	1	3
Sciuridae	8	16
Rhizomyidae	0	1
Muridae	4	13
Hystricidae	1	2
Manidae	0	1
Mustelidae	0	2
Viverridae	1	5
Felidae	0	2
Tragulidae	1	2
Suidae	0	1

Although impoverished, the Tioman fauna shows considerable diversity, and few major ecological niches remain unfilled. Apart from the large game animals, the most significant mammalian group lacking comprises the predacious carnivores, absent at all altitudes from all habitats, aquatic, terrestrial and arboreal. Also absent are large primates of the canopy (gibbons and leaf-monkeys), and several other specialised mammals or groups of mammals: the termite-eating Pangolin (*Manis*), mammals of fresh-water (otters, water shrew, Moonrat), or the group associated with bamboo (*Rhizomys, Chiropodomys, Tylonycteris*).

On the other hand, offsetting the paucity of species, the number of individuals in several cases is very great. The following non-flying mammals have been noted as very distinctly more abundant (in some cases only within restricted habitats) than in equivalent habitats on the mainland: *Crocidura malayana, Tupaia glis, Ratufa bicolor, Callosciurus notatus, Sundasciurus tenuis, Lariscus insignis, Rattus* sp. *tiomanicus, Rattus exulans, Rattus sabanus, Rattus surifer, Atherurus macrourus, Tragulus napu.* In the case of small mammals of the forest floor and lower arboreal storeys, trapping results support our subjective assessments of abundance. In all habitats combined, lines of baited cage traps in over 700 trap day/nights caught an average of 36.2 small mammals per 100 trap day/nights (see Table 3). Excluding cultivated and fringing lands, in forest habitats alone in 451 trap day/nights 129 mammals were trapped, an average of 28.6 per 100 trap day/nights. Comparable

figures based on much longer trapping runs in field habitats on the mainland have kindly been made available by Professor J. L. Harrison (Table 8). His "Forest" habitat evidently includes some fringing land (in which trapping is more likely to be successful) but nonetheless yielded only 5.0 animals per 100 trap nights. Thus trapping figures indicate that the total biomass of small mammals of the ground and lower storeys of the forest on Tioman may exceed five times the biomass of small mammals of this habitat in mainland forest.

TABLE 8

Mammals trapped near Kuala Lumpur by the Scrub Typhus Research Unit, Institute for Medical Research, during the years 1948 to 1950
(Data kindly made available by J. L. Harrison)

Habitat*	No. of Trap Nights	Catch per 100 Trap Nights
Town	65,000	9.5
Scrub	12,000	5.5
Forest	65,000	5.0
Oil Palm	18,000	6.0

* The habitats and methods of investigation were as follows: *Town* — trapping carried out in houses by householders; *Scrub* — a variety of lightly wooded terrain ranging from the edge of rubber plantations through parkland, *Melastoma* bushes, to open lalang grassland; *Forest* — trapping by aborigines in forest, and among their gardens and ladang; *Oil Palm* — trapping by estate labourers in the Elmina Oil Palm Estate, Sungei Buloh

Some of the strikingly abundant mammals (*Callosciurus notatus, Rattus exulans,* and *Rattus* sp. *tiomanicus* in cultivated areas) feed largely on crop plants or associated weeds; others (for instance *Atherurus macrourus*) may depend on crops to a considerable extent. But an equal number of very common species are as clearly quite independant of crop plants as a food source (*Crocidura, Lariscus, Rattus surifer, Tragulus*). By inference it is doubtful that the wholly or partly dependant groups owe their abundance solely to the presence of these crops.

To some extent the absence of elements of the mainland forest fauna must have permitted the species on Tioman to exploit ecological niches normally occupied by closely related and competitive forms. An obvious example is *Rattus tiomanicus,* which is common throughout the island, occupying an even wider range of habitats than those that on the mainland are divided among three forms of the *Rattus rattus* group, the commensal *diardi,* the ricefield *argentiventer,* and the field and woodland *jalorensis.*

Morphological evidence suggests that *R. surifer* of Tioman is more significantly insectivorous than the mainland form. This is supported by trapping figures, which indicate that this rat (with *Hylomys*) replaces the primarily insectivorous treeshrew in the forest habitat at higher altitudes (Table 3 and cf. Dunn, this *Bulletin,* later). This modification however would represent a shift rather than a broadening of the ecological niche. There is also some evidence that a reverse shift, away from a diet rich in insects towards a diet primarily vegetarian, may have taken place among *R. sabanus.*

On the other hand, there are also several striking instances of ecological conservatism. For example, above 500 ft., in all storeys of the forest the medium-sized squirrel niche is unoccupied, although both *C. notatus* and *C. nigrovittatus* are

present at lower altitudes. On the mainland *C. notatus* is commonest in cultivated land, although it ranges far into primary forest, and *C. nigrovittatus* is more or less restricted to lowland forest. On Tioman, *C. notatus* is apparently less adaptable and rarely extends beyond plantations and the fringing forest. The encroachment of cleared land on the relatively narrow border of lowland forest has apparently restricted the habitat of *C. nigrovittatus* and brought it into competition with the more aggressive and successful *notatus*. The latter species is virtually commensal with man, and over much of its range undoubtedly owes its wide distribution to the extension of plantation crops, particularly coconut (cf. the situation on Tulai). The introduction of the coconut palm to Tioman is relatively recent, and the population of *C. notatus* may also have originated only in recent times.

Other examples of ecological conservatism are shown by *Rattus exulans*, which remains tied to houses and rice fields, and *Macaca*, which remains restricted primarily to lowland forest fringing on cultivated land. In all cases there may have been a marginal extension of the ecological niche, not brought out by our data, but overall there is no evidence that any small mammal, except *R.* sp. *tiomanicus*, owes its abundance on Tioman to the reduction of interspecific competition.

The one factor that convincingly accounts for the great abundance of all members of this varied group of small mammals is the absence of mammalian carnivores. Apart from snakes, monitor lizards and raptorial birds, there are no carnivorous animals on Tioman from which these small and medium-sized mammals are liable to predation. Harrison (1956) has suggested that in mainland habitats snakes account for about a quarter of all deaths of rats. The extreme abundance of small mammals on Tioman, despite the presence of predatory snakes (python and black cobra, see Hendrickson, this *Bulletin*, p. 67), emphasises the importance of mammalian predators, over and above any others, in controlling the arboreal and terrestrial small mammal population in the normal mainland forest habitat.

Of the remaining mammals, bats are probably more or less immune from predacious carnivores, and the population on Tioman is presumably limited by other factors. The scarcity of bats at higher altitudes on the island is not satisfactorily explained.

The macaque is hardly more abundant on Tioman than it is in stretches of fringing forest on the mainland where it is as little molested by man. Excluding the activity of man, the population of these large primates is probably controlled by factors other than predation.

With one exception, the remaining mammals (Flying Lemur, Slow Loris, flying squirrels, the Pencil-tailed Rat, and the civets) are principally aboreal and nocturnal. As a group they do not appear to be particularly abundant, except in unusual situations such as the fruiting durian trees at Setegap. But since none readily enter traps, and none are easy to collect by other means, a confident assessment of the populations cannot be given.

The exception is *Rhinosciurus*, the Shrew-faced Ground Squirrel, which we completely failed to record in 1962, although no previous account has indicated that it was rare on the island. Restricted island populations are often subject to semicyclic fluctuations in population, related to levels of disease and parasite infestation. The present evidence suggests that the population of the Shrew-faced Ground Squirrel may have suffered some such catastrophic downfall, leading even to extinction. We have no evidence that other Tioman mammals are subject to such variations. It was in fact noted that all specimens of all species handled were apparently fit and in good condition.

TABLE 9

Fecundity of small mammals on Tioman and on the Malayan mainland as shown by frequencies of litters (born or unborn) of stated size.

Species		Number of conceptuses							
		1	2	3	4	5	6	7	
Crocidura malayana	Tioman	1	—	—	—	—	—	—	Number of pregnant females
	Malaya				No data				
Cynocephalus	Tioman	1	—	—	—	—	—	—	
	Malaya				No data				
*Tupaia glis**	Tioman	—	1	—	—	—	—	—	
	Malaya	—	5	—	—	—	—	—	
*C. notatus**	Tioman†	—	3	1	—	—	—	—	
	Malaya	2	18	3	2	—	—	—	
R. tiomanicus	Tioman	—	—	—	1	—	—	—	
R. jalorensis‡	Malaya	2	3	31	27	11	2	1	
*R. exulans**	Tioman	—	—	1	1	—	—	—	
	Malaya	3	9	9	38	19	12	1	
*R. sabanus**	Tioman	—	—	—	1	—	—	—	
	Malaya	2	18	20	7	5	—	2	
*R. surifer**	Tioman	—	—	—	1	—	—	—	
	Malaya	—	2	9	3	2	—	—	
*R. cremoriventer**	Tioman	—	1	—	—	—	—	—	
	Malaya	—	1	4	3	2	—	—	

*All Mainland data from Harrison (1955).
†Tioman data includes one specimen collected by I.M.R.
‡Data for *R. jalorensis* from all habitats, in Harrison (1951).

One of the signs of overcrowding among a restricted island population is a reduction in fecundity (cf. Harrison, 1951). In Table 9, details of the number of conceptuses per pregnant female from Tioman and from mainland samples are given. Records from Tioman are too sketchy for statistical comparison. But the data available do not suggest that the fecundity of the rodents on the island is reduced below the mainland norm.

ORIGIN OF THE FAUNA

With the exception of *Hylomys*, the mammalian fauna of Tioman comprises only characteristic lowland species. The significance of the presence of *Hylomys* is greatly reduced by the archaeological discovery, already discussed, indicating that an apparently identical form occurred in the lowlands of Borneo in the late Upper Pleistocene. Admittedly the extent of land above the 2,500 ft. contour on Tioman is limited, but on Maxwell's Hill (3,400 ft.), Perak, an outcrop of comparable size and altitude on the mainland, the following montane rodents have been recorded (I.M.R., 1960): *Tamiops mcclellandi, Rattus bowersi, R. edwardsi, R. niviventer.* The comparison is a little stretched, for Maxwell's Hill is connected to the higher G. Hijau (4,751 ft.) but since *Hylomys* occurs on Tioman, it is likely that viable populations of other characteristically montane small mammals could also be supported. Their absence suggests the possibility that the existing fauna of Tioman represents not a relict, isolated by the submersion of the Sunda shelf, but an oceanic fauna built up by successive invasions from the adjacent Malayan lowlands.

This supposition would explain not only the absence of montane forms, but also the other apparently random anomalies in the list of lowland mammals represented on the island. It is supported by a comparison of the faunas of the three major outer islands of the Johore-Pahang archipelago, P. Tioman, P. Pemanggil and P. Aor (fig. 1). No mammal species occur on the two outer islands that do not also occur on Tioman, suggesting that colonisation took place across the sea barrier via Tioman, rather than by random isolation (Table 10). The progressive depletion of the fauna from the mainland, through Tioman, to the two distant islands is characteristic of an oceanic distribution. In addition the poverty of the faunas of Pemanggil and Aor is undoubtedly related also to the smaller size of two islands, and to the greater effect of recent human intervention on the natural flora (cf. P. Tulai). The apparent absence of *Crocidura* and *Cynocephalus* from Pemanggil may be due to the same factors, but may also be accounted for by the less intensive zoological collection that has taken place on the outer islands. The absence of the commensal *Rattus exulans* emphasises the role of man as carrier of this rat. It was probably introduced directly to Aor at a recent date.

TABLE 10

Mammals (excluding Chiroptera) of the outer islands of the Johore—Pahang archipelago

Species	Pulau Tioman	Pulau Pemanggil	Pulau Aor
Hylomys suillus	x		
Crocidura malayana	x		x
Cynocephalus variegatus ...	x		x
Tupaia glis	x	x	x
Nycticebus coucang	x		
Macaca fascicularis	x		
Ratufa bicolor	x		
Callosciurus notatus	x	x	x
Callosciurus nigrovittatus ...	x		
Sundasciurus tenuis ...	x		
Lariscus insignis	x		
Rhinosciurus laticaudatus ...	x		
Petaurista petaurista	x		
Iomys horsfieldi	x		
Rattus rattus group	x	x	x
Rattus exulans	x		x
Rattus surifer	x	x	x
Rattus sabanus	x		
Rattus cremoriventer	x		
Atherurus macrourus	x	x	x
Paradoxurus hermaphroditus ...	x		
Tragulus napu	x		
Total ...	22	5	8

With only one exception (*Crocidura malayana*), our additional material from Tioman has confirmed that the majority of non-flying mammals are distinct from the mainland forms, and has upheld subspecific separation. A general trend towards smaller size, and especially shortening of the tail, is shown. In only one instance (*Rhinosciurus laticaudatus*) does the endemic Tioman race resemble the Bornean more closely than the mainland Malayan form. However, since the

population of this squirrel on the intervening Anamba Is. is not distinguishable from the mainland form (Chasen, 1940), the Bornean resemblances of the Tioman population are clearly an instance of convergence and not of true affinity.

Apart from *R. exulans*, all the mammals of both Pemanggil and Aor have been further separated as endemic subspecies. Hill (1960) has shown that the pattern of subspeciation is again typical of a group of oceanic faunas with the most divergent forms occurring on the most distant islands, and intermediates on the inshore islands. An exception is *C. notatus* of P. Dayang, a small off-lier of P. Aor, which closely resembles the mainland race. It is very likely that the Dayang population of this virtually commensal squirrel represents a very recent introduction (perhaps with coconuts for planting direct from the mainland).

On the other hand, the faunas of the major islands of the Trengganu archipelago, some 240 miles to the north, show many similarities to the faunas of the Johore-Pahang group. The former are geographically quite unconnected to Tioman, although standing in approximately the same relation to the Malayan mainland. From the largest island, Pulau Redang, the following mammals (other than Chiroptera) have been recorded: *Crocidura* sp., *Tupaia glis, Macaca fascicularis, Callosciurus notatus, Sundasciurus tenuis, Rattus tiomanicus* group, *Rattus surifer* and *Tragulus* sp. (apparently *javanicus*); from P. Perhentian Besar, *Cynocephalus variegatus, Tupaia glis, Presbytis obscurus, Callosciurus notatus, Rattus tiomanicus* group, and *Rattus surifer;* from the smallest, P. Perhentian Kechil, *Cynocephalus variegatus, Tupaia glis* and *Callosciurus notatus* (all records from Kloss, 1911). In these instances, the similarities cannot be due to steppingstone colonisation. With the exception of the semicommensal *Rattus tiomanicus* group, which is probably very widespread in Asia, the mammals that occur most often on the islands of both archipelagoes (*Cynocephalus variegatus, Tupaia glis, Macaca fascicularis, Callosciurus notatus, Sundasciurus tenuis, Rattus surifer*) are all widespread throughout the major land masses of the Sunda shelf, with only a limited distribution beyond the region. The fact that the common members of these island faunas are all characteristic of the Sunda region suggests either that these forms are better adapted to cross the sea barrier, or that the same relict elements formed the basis of each island population. It is relevant that the diversity of the faunas throughout the whole group of east coast Malayan islands is in each case directly related to the size of the island.

Presumably both factors have operated. A proportion of the mammalian fauna comprises species that arrived after isolation by rafting or by the intervention of man, and the remainder represent relict populations of the ancient Sunda fauna. The number of relict species that survived isolation on each island could be expected to be related to the size of the exposed land surface, and consequently to be greatest on P. Tioman, the largest island of the group.

Archaeological work in the region has shown that equivalent subspecific variations have evolved since the late Quarternary in a number of mammals (Hooijer, 1949). Among restricted island populations subspeciation may occur at a very fast rate (e.g., Ashton & Zuckerman, 1950–51) and it is not necessary to postulate a very long period of isolation in order to explain the high rate of endemicity among the mammals of Tioman.

SUMMARY

Thirty-one species of land mammals are recorded from P. Tioman, and five from P. Tulai. These are listed in systematic order, and the distribution of each on the island, the food and reproductive condition of specimens examined, and the taxonomic relations of the island population are discussed in each case. The taxonomic separation of seventeen named forms from Tioman is upheld, and it is suggested that longer series might show that two other mammals also represent endemic island forms. The mammalian faunas of both islands are shown to be considerably depleted. On the other hand many species are shown to be much more abundant on P. Tioman than in equivalent habitats on the mainland. It is suggested that this abundance is related to the absence of predators, particularly carnivores, rather than to differences in ecological relations. The population of one mammal (*Rhinosciurus laticaudatus*) has apparently declined sharply during the last forty years or so, but other species show no signs of population fluctuation. It is suggested that the faunas of Tioman, and of other islands off the east coast of Malaya, represent relicts of the late Upper Pleistocene lowland Sunda mammalian fauna, supplemented on each island by later invaders, and depleted on each island in relation to the extent of exposed land surface.

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3. The specific relations of *Rattus tiomanicus* (Miller)

By LORD MEDWAY

and

B. L. LIM

INTRODUCTION

RATS OF THE subgenus *Rattus* are endemic on many of the islands off the coast of Malaya. In most cases each population is recognisably distinct from other island forms, and from related rats on the Malayan mainland. Many island forms have been described, including *R. tiomanicus* (Miller) the ecology of which has already been discussed (Medway, this *Bulletin*, p. 20). On the mainland three ecologically separated forms occur (Chasen, 1933), namely, the Malaysian House Rat, *diardii*[11] Jentink, the Malaysian Field Rat, *jalorensis* Bonhote, and the Ricefield Rat, *argentiventer* Robinson and Kloss. These three, together with all island forms, were listed by Chasen (1940) as subspecies of *R. rattus* (Linn.) However, Harrison (1961) has surveyed the distribution of these and related rats throughout Eurasia and adjacent regions, and has suggested that the three forms are best regarded as distinct species of *Rattus*, "each of which is a commensal with man, which have been separately introduced into Malaysia, and which have not yet wholly occupied the area" (Harrison, 1961: 23). Independently, Dhaliwal (1962 & 1963) has undertaken a detailed morphological comparison of series of *jalorensis* and *diardii* from two Malaysian localities, and has shown statistically that the two taxa are distinguished by differences of species rank. Both Harrison (1961) and Dhaliwal (1962) have also noted that several of the island forms are little differentiated from *R. jalorensis*, and are better considered races of this species rather than of *R. rattus*.

On the other hand, on Singapore Island (where *argentiventer* is unknown) *jalorensis* occurs only in a very restricted area, probably having been absent until recently (Searle and Dhaliwal, 1961). On the Malayan mainland, in localities where they are sympatric, *jalorensis*, *argentiventer* and *diardii* are separated by habitat preference; but if one or more is absent, the remaining species characteristically expands to occupy the vacant niches (Harrison, 1957). Similarly in Singapore *diardii* occurs in a wide range of habitats, including not only houses but also field and fringe habitats that on the mainland are occupied by *jalorensis* (Dhaliwal, 1961).

R. argentiventer is the more highly specialised rat, and its distribution is limited by its relatively stringent ecological demands. But it is clear that either of the more adaptable *diardii* or *jalorensis* may occur on islands, and that in the absence of competition either may exploit an equally wide range of habitats. Consequently the ecology of an island form is no indication of its taxonomic relations.

It appears from the distribution of *jalorensis* on Singapore Island that the species has entered only recently. By inference, the narrow sea barrier of the Straits of Johore had hitherto effectively prevented the spread of this rat. *R. jalorensis* is probably the older commensal rat in mainland S.E. Asia and *diardii* a more

11. The emended spelling *diardi* is preferable to the original *diardii*, (which was used by Chasen. *loc. cit.*), see the *International Code of Zoological Nomenclature* (1961 edition). Article 31, Article 32 (*c*), and Appendix *D* (III) 16 (*b*).

recent introduction (Harrison, 1957). But the case of Singapore Island stresses that it is not possible to assume on theoretical grounds that an island form such as *tiomanicus* is a race of the more ancient species. In fact it is clear that under modern conditions the cosmopolitan *diardii* is better equipped than *jalorensis* to cross the relatively broad sea barrier.

It is characteristic of island situations of this sort, where one of two closely related and normally exclusive species is absent, that the population of the species that is represented should be intermediate in character (e.g., also among Muridae, Cranbrook, 1957). This is true of *tiomanicus,* and it is by no means clear on superficial inspection to which species this island rat should be ascribed. In the present contribution we have attempted to assess the specific relations of *tiomanicus* by detailed comparison of morphological characters.

MATERIALS

Measurements of *tiomanicus* are taken from a series of 28 adults of both sexes collected by us from the main island; we have also included 9 adults of both sexes from P. Tulai. For *diardii* and *jalorensis,* where we have not made use of Dhaliwal's published measurements, our figures are based on a series of 17 *diardii* and 18 *jalorensis,* adults of both sexes, collected from Selangor.

The preserved material is divided among the collections of the Institute for Medical Research and the Department of Zoology, University of Malaya.

COMPARISON OF CHARACTERS

EXTERNAL CHARACTERS

The dorsal pelage of *R. jalorensis* is brown, and relatively sleek with only a slight admixture of soft spines; the venter is white to greyish white. The dorsal pelage of *R. r. diardii* is also brown, but is coarser and harsher; the venter on the mainland is usually brownish grey, but among the population on Singapore Island varies in colour from this shade through grey to nearly white. Dhaliwal (1963), by microscopic study of the hair types, has shown that auchenes and zigzags of the ventral pelage are always unpigmented in *jalorensis,* and always pigmented in even the palest *diardii* and in hybrids between the two forms. Topotypes of *tiomanicus* resemble *jalorensis* dorsally, but ventrally vary like *diardii* from brownish grey through grey to greyish white; both auchenes and zigzags of the venter may be pigmented. The population on Tulai is distinguished by a pure white venter.

Where the two forms are sympatric, *diardii* and *jalorensis* are also readily distinguished by measurement. In Table 1 the principal dimensions in the flesh of two populations of *diardii* and *jalorensis* (from Dhaliwal, 1962) and of our series from Tioman and Tulai are compared. The mean head and body length of *tiomanicus* topotypes is within the total range of variation of *jalorensis* from the two localities; it is also not significantly different from the mean head and body length of Singapore *diardii*. The mean head and body length of the series from Tulai is larger, although not significantly larger than that of Singapore *jalorensis*. In both series the tail is generally longer than the head and body, a characteristic of *diardii* rather than of *jalorensis* (mean $\frac{T}{HB}$% is 101.5 ± 1.3% for *tiomanicus* topotypes, 106.5 ± 2.1% for the Tulai series). The hind feet are intermediate in length. The ear is within the range of variation of *diardii,* and significantly larger than the ear of *jalorensis*.

TABLE 1

Principal measurements of *diardii*, *tiomanicus* and *jalorensis*, in mm given as means ± S.E. of mean. Figures for *diardii* (Singapore and Selangor) from Dhaliwal (1962).

	diardii (Singapore)	*diardii* (Selangor)	*tiomanicus* (Tioman)	Tulai rat	*jalorensis* (Selangor)	*jalorensis* (Singapore)
Head and body	184.4±1.7	170.8±3.1	170.8±2.0	178.3±2.8	167.7±1.3	176.9±2.6
Tail	186.9±1.9	180.5±4.2	174.1±2.1	189.3±5.4	160.6±1.3	158.8±4.3
Hind foot	35.2±0.2	35.0±0.4	33.3±0.2	34.4±0.1	31.7±0.2	32.7±0.3
Ear	20.4±0.2	21.3±0.3	20.7±0.1	20.6±1.0	19.4±0.1	19.8±0.3
Occipitonasal length of skull	41.5±0.2	41.6±0.3	41.9±0.9	41.3±0.1	40.2±0.4	40.6±0.9
Length of right anterior palatatal foramen ..	7.7±0.05	7.7±0.1	6.8±0.1	7.0±0.7	6.8±0.05	7.1±0.1
Maxillary toothrow	7.1±0.05	7.1±0.04	6.7±0.04	6.6±0.1	6.8±0.04	6.7±0.05

The hindfoot of *diardii* as well as being absolutely longer is also proportionately longer than the hindfoot of *jalorensis;* in this character *tiomanicus* is again intermediate. The proportions *length of hind foot: length of head and body,* expressed as the mean of the percentages ± S.E., are as follows: *diardii* (Selangor) 19.8 ± 1.3%, *jalorensis* (Selangor) 18.8 ± 0.8%, *tiomanicus* (topotypes) 19.5 ±0.6%, from P. Tulai 19.3 ± 0.2%.

SKULL CHARACTERS

Skull measurements are also given in Table 1. It is seen that the skull of *tiomanicus* is larger, in occipitonasal length comparable to *diardii* and not *jalorensis*. On the other hand certain important features of the skull, notably the small anterior palatal foramen and the short toothrow, are closely compatible with *jalorensis,* and significantly different from *diardii* of all localities.

Dhaliwal (1962) has suggested that the foramen magnum of *jalorensis* tends to be more ventrally placed than that of *diardii*. Any significant difference in this character between the two taxa should be revealed by the ratio *basal length* : *occipitonasal length,* where basal length is measured from the anterior margin of the foramen magnum. We have analysed both this ratio from measurements of *diardii* and *jalorensis* from Selangor, and the ratio *condylobasal length* : *occipitonasal* length, from Dhaliwal's original measurements of his series from Singapore and Selangor. We find that there is wide individual variation within both taxa, without significant difference between the means. We conclude that this character cannot be used to distinguish between the species.

There is one other important skull character that cannot be reduced to metrical terms. This is the degree of development of the supraorbital ridges, which are more pronounced in *diardii* than in *jalorensis* (Dhaliwal, 1962). We find that in *diardii* these ridges extend forward distinctly to the base of the zygomatic arch on the jugal, whereas in *jalorensis* they terminate at a point posterior to the posterior suture of the jugal behind the base of the zygomatic arch. Using this character we are able to pick out skulls of *diardii* and *jalorensis* from mixed collections with very few mistakes. In this character too, the skull of *tiomanicus* is not intermediate but is decidedly of the *jalorensis* type, readily distinguished from that of *diardii*.

DISCUSSION

In Table 2, the principal characters of *R. tiomanicus* are summarised, and the relations that they suggest are indicated. It is seen that there is a predominance of characters indicating affinity with *jalorensis*. Moreover three of these characters relate to the anatomy and proportions of the skull rather than to absolute size. Discussion of the mammalian fauna of Tioman (Medway, this *Bulletin,* p. 24) has already shown that the endemic subspecies of rats and other rodents on the island may be distinguished from their mainland congeners by appreciable variations both in pelage coloration and in body size and proportion (particularly in the length of the tail). By inference, affinities indicated by characters of this nature are significant only at the subspecific level, and are not reliable indicators of specific relationship.

We therefore attach considerably more importance to the three skull characters listed, all of which are noted by Dhaliwal (1962: 258) among the essential differences between *jalorensis* and *diardii*. On the basis of these characters, we suggest that *tiomanicus* should be regarded as conspecific with *jalorensis* rather than with *diardii*[12].

12. Attempts to produce hybrids with other forms were not successful. Sixteen *tiomanicus* were brought back from the island and paired as follows: 4 with *jalorensis*, 4 with *diardii,* and 8 with *jarak* Bonhote, the form endemic on P. Jarak in the Straits of Malacca, which has crossed freely with *jalorensis* in captivity at the I.M.R. We have no evidence of fertile matings from any of these pairs.

TABLE 2

Affinities of the principal characters of topotypical *tiomanicus* (measurements in mm.)

Resembling *diardii*	Intermediate	Resembling *jalorensis*
Ventral pelage grey-brown to pale grey; auchenes and zigzags both pigmented		Dorsal pelage relatively sleek.
Tail generally greater than 100%HB	Mean head and body length 170.8±2.0	
	Mean hindfoot length 33.3±0.2 →	
	← Mean ear length 20.7±0.1	
Occipitonasal length of skull 41.9±0.9		Length of anterior palatal foramem 6.8±0.1
		Length of maxillary toothrow 6.7±0.04.
		Supraorbital ridges relatively weekly developed.

The variation in ventral coloration is probably related to habit (cf. Harrison, 1961). The venter of the house and town dwelling *diardii* of mainland Malaya is greyish brown, but on Singapore Island where this form occupies a wide range including field and fringe habitats, the ventral coloration is very variable, from greyish brown to pale grey (Dhaliwal, 1963). Conversely *tiomanicus*, although apparently descended from a white-bellied form, shows considerable darkening in ventral coloration in accordance with its range of habitats including close commensal situations. On P. Tulai only the field habitat is available, and the rat population is, like mainland *jalorensis*, white bellied. The rat of Tulai is significantly larger than *jalorensis* and is as distinct as many of the island forms that have been described as separate subspecies. Its affinity with *tiomanicus* and *jalorensis* is again indicated by the skull characters discussed.

The name *tiomanicus* dates from 20th August, 1900 (*Proc. Wash. Acad. Sci.*, 2: 209), and is in fact the oldest name available for the pale-bellied field rats of Malaysia. The name *tiomanicus* was used by Sody (1941) to designate this group, although subsequent authors have preferred to preserve the epithet *jalorensis*. It is an unfortunate result of the international rules of nomenclature that the older name, albeit applied only to an island population, must take precedence, so that the name *jalorensis* is superceded as specific epithet for the Malaysian Field Rat.

Harrison (1961) has discussed the white-bellied forms occurring outside this region. From India the oldest name available appears to be *brunneusculus* Hodgson 1845; this in turn is antedated by *frugivorus* Rafinesque 1814, the white-bellied form of the Mediterranean region (Ellerman and Morrison-Scott, 1951). However, in view of the obvious plasticity of the group, the demonstrated unreliability of ecology as a taxonomic indicator, and the probable relationship between ecology and ventral coloration, we hesitate to suggest that these may all be conspecific. We do not have material available to assess the wider relations of the *tiomanicus* group, but we suggest that the most profitable approach is likely to be based on the features of skull anatomy discussed above, rather than on other morphological characters.

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4. The Birds

By LORD MEDWAY

INTRODUCTION

EARLIER expeditions to Tioman (principally those already listed by Bullock and Medway, this *Bulletin*, p. 9) have effectively sampled the resident avifauna. Although no formal list of the birds of Tioman has been published, scattered accounts exist, and details of distribution and taxonomy have been summarised in Chasen (1935) and/or Gibson-Hill (1949). The two are not always consistent.

In this paper are listed all land and shore birds so far recorded from the island. Species recorded on our recent trip which had not hitherto been unambiguously attributed to Tioman or the Tioman archipelago (i.e., discounting vague embracing phrases such as "most offshore islands", "most suitable islands") are marked with an asterisk. The order and numbering follow Gibson-Hill (1949), but systematic names have been revised and English colloquial names are taken from McClure's Standard list for S.E. Asia (1963).

Of the 37 species of presumably resident birds, eight have in the past been distinguished subspecifically from mainland Malayan forms. Only one of these subspecies is endemic to the island (*Stachyris nigriceps tionis*); the remainder also occur elsewhere, on more distant islands to eastward in the South China Sea (Table 1).

TABLE 1

Birds of Tioman: distribution of subspecies that have been distinguished from mainland Malayan forms

Trinomial	Distribution
Treron vernans adina (Oberh.)*	Tioman; Anamba Is.; Natuna Is.
Pycnonotus plumosus chiroplethis Oberh.	Tioman; Anamba Is.
Pycnonotus brunneus zapolius Oberh.*	Tinggi (? and Tioman); Anamba Is.
Stachyris nigriceps tionis Rob. & Kloss.	Tioman.
Orthotomus atrogularis major Chas. & Kloss.	Tioman; Anamba Is.
Gracula religiosa prasiocara Oberh.*	Tioman; Anamba Is.; Tambelan Is.
Aplonis panayensis heterochlorus Oberh.*	Tioman & Aor; Rhio Archipelago; Anamba & Tambelan Is.; Natuna Is.; North Bornean Is. including Mantanani & Karimata.
Dicrurus paradiseus microlophus Oberh.	Tioman; Anamba Is.; N. Natuna Is.

*Not admitted by Gibson-Hill (1949).

We did not, in March – April 1962, attempt to collect series of skins, and available material does not permit any reassessment of the validity of these races. A few birds were collected, usually in order to verify identification; these were examined for ectoparasites and skinned. The skins are now in the collection of the Zoology Department, University of Malaya. But most of the observations given below are based on sight records, or on birds that were mist-netted and released after inspection and collection of ectoparasites.

ANNOTATED LIST

THE BIRDS OF TIOMAN

10. Fregata andrewsi Mathews. Christmas Island Frigate-bird.

11. Fregata ariel (Gray). Least Frigate-bird.

We confirmed previous observations (Gibson-Hill, 1950) that both frigate-birds habitually roost (but do not breed) on Pulau Rengis, off the west coast of Tioman (fig. 1). This tiny islet, consisting of no more than a steep pile of very large granite boulders, supports a close cover of stunted trees none of which exceed 20 feet in height. Characteristically, the frigate-birds gather over the island at sunset but do not come in to roost until nightfall, when they appear to settle on the ends of the bigger branches. They leave again at first light. 37 birds were counted off at dawn on 5th April, but many more were judged to be present on the evening of 7th April when a male and female of each species were collected.

Previous observers have found frigate-birds on Tioman between May and July. It remains to be ascertained whether they are in fact present throughout the year.

15. Butorides striatus (Linn.). Little Green Heron.

Several observations in the narrow strip of mangrove behind the rest-house at Tekek; also a solitary bird on the rocky foreshore south of Kg. Lalang, 28th March.

22. Egretta sacra (Gmelin). Reef Egret.

We found four individuals, all in the commoner grey phase, consistently present on the beach near Tekek; and one, also grey, was to be seen every day at Mokut during our stay there. Off Kg. Genting is a sea rock regularly used as a roost, much stained with droppings.

48. Haliastur indus (Boddaert). Brahminy Kite.

Present at Tekek, but not venturing far inland. Not recorded at Mokut.

60. Haliaeetus leucogaster (Gmelin). White-bellied Sea Eagle.

Common and conspicuous, restricted to the beach and close offshore. At least three individuals were consistently present in Tekek bay; one of them an immature apparently still dependent on its parents.

In a two-day circumnavigation of Tioman, Dunn observed 13 different White-bellied Sea Eagles, and this figure probably represents the total adult population. Daytime roosts were plotted (fig. 3) and show an even distribution around the island, giving an average density of one bird per 2.9 miles of coastline.

***71. Spilornis cheela** Latham. Serpent Eagle.

Recorded inland only, never over the beach. From the sea a single bird was seen circling over forest at the foot of Nenek Si-Mokut (15th April); near Camp II its distinctive call was heard several times; and inland of Tekek, a single bird was watched for some time (23rd April) being mobbed by a pair of racquet-tailed drongos.

***74. Falco peregrinus** Tunstall. Peregrine Falcon.

During our week at Mokut (8–14th April) one or two peregrines were seen every hot day, circling in the thermals off the cliff faces of the Nenek Si-Mokut outcrop. No other records. On hot days these thermals attracted a number of raptors, some of which could not be identified.

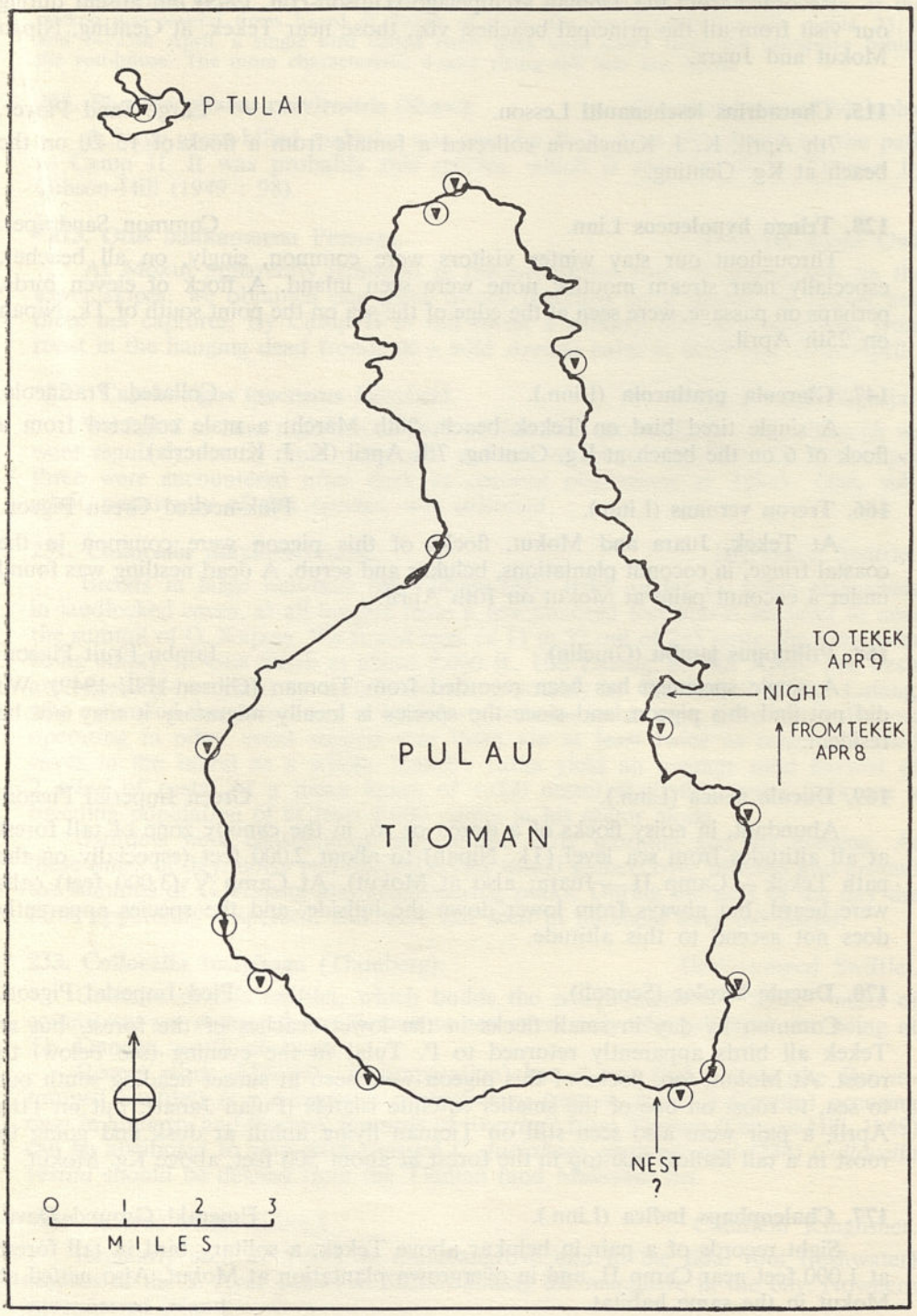

Figure 3. Sketch map of Pulau Tioman, showing distribution of White-bellied Sea Eagle population.

113. Charadrius peroni Schlegel. Malay Sand Plover.

Recorded from the Tioman archipelago (Gibson-Hill, 1949) but absent during our visit from all the principal beaches, viz., those near Tekek, at Genting, Nipah Mokut and Juara.

115. Charadrius leschenaulti Lesson. Large Sand Plover.

7th April, K. J. Kuncheria collected a female from a flock of 15–20 on the beach at Kg. Genting.

128. Tringa hypoleucos Linn. Common Sandpiper.

Throughout our stay winter visitors were common, singly, on all beaches, especially near stream mouths; none were seen inland. A flock of eleven birds, perhaps on passage, were seen at the edge of the sea on the point south of Tk. Nipah on 25th April.

147. Glareola pratincola (Linn.). Collared Pratincole.

A single tired bird on Tekek beach, 28th March; a male collected from a flock of 6 on the beach at Kg. Genting, 7th April (K. J. Kuncheria).

166. Treron vernans (Linn.). Pink-necked Green Pigeon.

At Tekek, Juara and Mokut, flocks of this pigeon were common in the coastal fringe, in coconut plantations, belukar and scrub. A dead nestling was found under a coconut palm at Mokut on 10th April.

168. Ptilinopus jambu (Gmelin). Jambu Fruit Pigeon.

A single specimen has been recorded from Tioman (Gibson-Hill, 1949). We did not find this pigeon, and since the species is locally migratory it may not be resident.

169. Ducula aenea (Linn.). Green Imperial Pigeon.

Abundant, in noisy flocks of a dozen or so, in the canopy zone of tall forest at all altitudes from sea level (Tk. Nipah) to about 2,000 feet (especially on the path Tekek — Camp II — Juara; also at Mokut). At Camp V (3,000 feet) calls were heard, but always from lower down the hillside, and the species apparently does not ascend to this altitude.

170. Ducula bicolor (Scopoli). Pied Imperial Pigeon.

Common by day in small flocks in the lower reaches of the forest, but at Tekek all birds apparently returned to P. Tulai in the evening (see below) to roost. At Mokut, too, flocks of this pigeon were seen at sunset heading south out to sea, to roost on one of the smaller satellite islands (Pulau Jahat); but on 11th April, a pair were also seen still on Tioman flying uphill at dusk and going to roost in a tall leafless tree top in the forest at about 500 feet, above Kg. Mokut.

177. Chalcophaps indica (Linn.). Emerald Ground Dove.

Sight records of a pair in belukar above Tekek, a solitary bird in tall forest at 1,000 feet near Camp II, and in overgrown plantation at Mokut. Also netted at Mokut in the same habitat.

***190. Cacomantis merulinus** (Scopoli). Plaintive Cuckoo.

No formal record; but a long descending call resembling one of the two calls of this cuckoo was several times heard at Tekek at dusk. On two brightly moonlit nights, 23/24 and 24/25th April, a single bird called from dusk until dawn from the mangrove behind the rest-house. The more characteristic 4-note rising call was not heard.

203. Phaenicophaeus curvirostris (Shaw). Chestnut-breasted Malcoha.

A large green-billed malcoha was seen by B. L. Lim (8th April) on the path to Camp II. It was probably this species, which is recorded from Tioman by Gibson-Hill (1949 : 98).

***213. Otus bakkamoena** Pennant. Collared Scops Owl.

At Mokut apparently common in the overgrown coconut plantations on the lower slopes; we obtained one sight record (perched on a branch by night) and three net captures. By Camp II in tall forest a solitary bird was disturbed from roost in the hanging dead fronds of a wild *Arenga* palm at 0645 hrs., 27th April.

***229. Caprimulgus macrurus** Horsfield. Long-tailed Nightjar.

We failed to hear nightjars at dusk or dawn on any occasion, and although we were regularly out by night only once did any of us see nightjars. On 12th April three were encountered after dark in coconut plantations at Tekek. One, sub-adult, apparently of this species, was collected.

231. Collocalia maxima Hume. Black-nest Swiftlet.

Breeds in large numbers (cf. Gibson-Hill, 1948, under *C. lowi*) exclusively in landlocked caves, at all heights from a few hundred feet above sea-level to near the summit of G. Kajang. We found eggs (♂ 1) in 32 out of 215 nests, the remainder being empty, at Gua Sinah at about 2,000 ft., Ulu Lalang, on 5th April. The nests are regularly harvested by certain islanders, notably by Che Ismail of Kg. Lalang, who estimated that there were at least forty colonies in his beat; talks with collectors operating in other areas suggest that there are at least twice as many occupied caves in the island as a whole. Ismail's caves yield an average total harvest of 2 *pikul* of nests. At a mean figure of 4,000 nests/*pikul*, this figure indicates a breeding population of at least 8,000 adults in his sector alone.

Swiftlets were conspicuous only in the early morning and the evening. At these times of day, noisy and excited flocks would gather, over beaches and around the summits of G. Kajang and neighbouring peaks. During the heat of the day the birds apparently dispersed, and were not seen in numbers over the island.

233. Collocalia fuciphaga (Thunberg). Grey-rumped Swiftlet.

Colonies of this swiftlet, which builds the much esteemed "White" nests of commerce, are restricted on Tioman to sea caves only, the principal site being at Tk. Dungun, north of Juara.

Recent work (Medway, in preparation) has shown that *vestita* (the Brown-rumped Swiftlet) is a subspecies of *fuciphaga* (not = *francica* Gmelin) occuring only in Sumatra and Borneo. Records of "*vestita*" from Tioman (Gibson-Hill, 1949) can be attributed to very dark-rumped *C. fuciphaga germani;* and (234) *Collocalia vestita* should be deleted from the Tioman (and Malayan) list.

***250. Alcedo atthis** (Linn.). Common Kingfisher.

Regularly seen at Tekek in the mangrove and in the tidal (but freshwater) reaches of the S. Ayer Besar; at Mokut among the mangrove in the bay. Nowhere encountered inland.

258. Halcyon coromanda (Latham). Ruddy Kingfisher.

Recorded from Tioman (Gibson-Hill, 1949: 120) but not seen by us.

261. Halcyon chloris (Boddaert). White-collared Kingfisher.

Common and definitely not "relatively scarce" (Gibson-Hill, 1949 : 121) in the narrow strip behind the beach all round the island; observed at stream-sides; in mangrove and among coconut palms.

***268. Eurystomus orientalis** (Linn.). Broad-billed Roller.

A party of 6–7 flying along Mokut beach, 9th April. Single birds also seen at Mokut in open cultivated land on 10th and 12th April.

(No woodpeckers were observed, although Wells, Dunn and Medway all independently heard an indefinite tapping near Camp II.)

332. Hirundo rustica Linn. Barn Swallow.

333. Hirundo tahitica Gmelin. Pacific Swallow.

Swallows were abundant on the beach at Tekek on our arrival. They were still there, in considerably reduced numbers when we left (27th April). Large flocks of an unidentified swallow were roosting on P. Rengis.

350. Dicrurus paradiseus (Linn.). Greater Racquet-tailed Drongo.

Probably the most widely distributed bird on the island, this drongo was common and conspicuous in all habitats from mangrove, open planted areas, ladang and orchards, through belukar and secondary forest, to tall forest at all altitudes up to and including the ridge at 3,050 ft. at Camp V. Characteristically it was noisy, showy and unafraid.

359. Corvus sp.

We were told by Che Ismail that crows occasionally visit Tioman. Their appearance is sufficiently rare to be considered a bad omen, foretelling a death.

377. Malacopteron magnirostre (Moore). Brown-headed Tree Babbler.

Common in tall forest up to 3,000 ft., although not seen on the ridge itself at Camp V, nor on the summit of G. Kajang. Typically encountered in small parties of 3 to 4, foraging in the undergrowth at shrub level.

385. Napothera brevicaudata (Blyth). Streaked Wren Babbler.

This montane bird is recorded from Tioman, but we failed to see it.

390. Stachyris nigriceps Blyth. Grey-throated Tree Babbler.

On 20th April a nest of this species, with two downy young, was found in a bushy rattan plant, 3 ft. from ground level, at c. 1,200 ft., Ulu Lalang. The nest was a deep cup, half-domed, 14 cm. high by 8 cm. diameter. The outer casing consisted of dry, dead leaflets of rattan; the inner lining, of fibres of palm spathes, etc. along with very soft fibres apparently derived from decomposed monocotyledenous leaves.

Both the nest and its siting accord well with descriptions in Chasen (1939: 301).

407. Alcippe poiocephala (Jerdon). Common Nun Babbler.

A simple descending seven-note call, widely heard in forest from Camp II to the slopes below Camp V, was tentatively identified as this species (D. R. Wells).

413. Aegithina viridissima (Bonaparte). Green Iora.

Recorded from Tioman by Chasen (1935). Not seen by us.

***423. Pycnonotus atriceps** (Temminck). Black-headed Bulbul.

A sight record by Dunn, in scrub at the edge of mangrove at Kg. Tekek.

433. Pycnonotus plumosus Blyth. Large Olive Bulbul.

Stated to occur on Tioman by Gibson-Hill (1949), but Chasen (1935 : 201) records it only from nearby P. Tinggi. We did not see this bulbul and its inclusion in the island list remains tentative.

434. Pycnonotus brunneus Blyth. Red-eyed Brown Bulbul.

Common in the southern part of the island, particularly in open country, orchards and plantations, but also observed in forest on the hill-sides up to 2,000 ft. in Ulu Lalang.

A nest, from which one fully fledged young was disturbed, was found at Mokut on 12th April, in the crown of a small (12 ft. high) isolated tree in the middle of harvested ladang. The nest was cup-shaped, measuring 11.5 cm. in diameter and 8 cm. deep externally, the inside of the cup being 9 cm. in diameter and 3.5 cm. deep. The materials used were as follows: outer casing, broad leaves, leaf stalks and midribs, interspersed with flecks of kapok; middle layer, principally broad strips of dry banana leaf with a certain amount of shredded graminaceous material including a threshed ear of rice; cup lining, dark fibres of *Arenga*.

441. Hypsipetes criniger (Blyth). Hairy-backed Bulbul.

Found only in the undergrowth of tall forest, both around Camp II, and on the ascent to Camp V at 1,500 ft.

450. Copsychus saularis (Linn.). Magpie Robin.

Recorded at Tekek, Nipah and Mokut, where it is common in open country around the villages, and among coconuts.

451. Copsychus malabaricus (Scopoli). Common Shama.

Common in forest at all heights, from tall belukar behind Tekek up to the penultimate ridge of G. Kajang.

482. Orthotomus atrogularis Temminck. Black-necked Tailorbird.

Abundant in bushes and scrub, including *Lantana* thickets, and secondary jungle around Kgs. Tekek, Mokut and Lalang. On G. Kajang it was also heard in the bamboo zone, and was the only bird apparently resident in the scrub on the summit, where an adult and a juvenile were seen immediately after dawn. At Mokut a family of three fledglings with one adult were seen on 10th April.

***?505. Muscicapa ?mugimaki** Temminck. Black-and-orange Flycatcher.

A sexually dimorphic flycatcher was present in small numbers on the high ground around Camp V and on the summit of G. Kajang, 16th April. Field notes describe the male as all dark above, with an impression of slaty blue, and a distinct wingbar; breast orange and abdomen white. The female was olive-brown above, with breast orange and abdomen dark. As so often with flycatchers, these notes leave the identification in considerable doubt, and I include the record only for the sake of completeness.

518. Motacilla flava Linn. Yellow Wagtail.

Two birds seen on the beach on 8th April. A flock of eight in breeding plumage feeding in harvested ladang at Tekek, 24th April. A female was collected from the latter group, and is attributable to *M. f. simillima.*

526. Aplonis panayensis (Scopoli). Philippine Glossy Starling.

Large garrulous flocks were recorded at Tekek, along the beach and especially into coconut plantations, and at Mokut. Large flocks also roosted on P. Rengis.

533. Gracula religiosa Linn. Hill Myna.

In the region of Tekek and Juara equally abundant in the coastal strip among coconuts and in tall forest all the way to Camp II. At Mokut slightly less conspicuous, but still very common in the cultivated subcoastal fringe. On high ground it was present up to 2,500 ft., below Camp V, but relatively scarce at this altitude.

535. Anthreptes malacensis (Scopoli). Brown-throated Sunbird.

At Tekek and Mokut common in coconuts and fringing belukar.

539. Nectarinia sperata (Linn.). Van Hasselt's Sunbird.

At Tekek in mangrove behind the rest-house, in tall secondary forest, in belukar on the forest edge, and an uncertain sight record in the subcanopy level of tall forest near Camp II. At Mokut in orchards and plantations; and at T. Nipah in mangrove. Males were aggressive and singing strongly; one male collected had enlarged testes.

541. Nectarinia jugularis (Linn.). Yellow-breasted Sunbird.

Observed at Tekek and Juara in or near patches of mangrove. It was not seen at Nipah, in the more restricted area of mangrove there, nor elsewhere where there was no mangrove.

***552. Dicaeum cruentatum** (Linn.). Scarlet-backed Flowerpecker.

Sight records of three birds (both sexes) in mangrove and coconut at Tekek (Dunn.).

***562. Zosterops ? palpebrosa** (Temminck). Oriental White-eye.

A single bird, fitting this species in general character, and with a distinct eye-ring, seen in the mangrove of Tekek, 6th April, and at least two birds seen in belukar edge near Kg. Tekek, 8th April (Dunn). These sight records constitute the first published observation of white-eyes not only on Tioman but also anywhere on (or off) the east coast of Malaya.

***569. Lonchura striata** (Linn.). Sharp-tailed Munia.

At Tekek and Mokut small flocks of 3–8 were regularly feeding in rice stubble on the hillside. At Tekek two were collected; their stomachs contained rice and grass seeds.

THE BIRDS OF TULAI

(3–5th April, 22–23rd April)

10/11. Fregata sp. Frigate-Birds.

Frigate-birds were seen over the island by day only.

15. Butorides striatus (Linn.). Little Green Heron.

22. Egretta sacra (Glmelin). Reef Egret.

4–5 present on the island, in the grey phase; cf. the Tekek flock.

48. Haliastur indus (Boddaert). Brahminy Kite.

During 3–5th April, there was considerable movement of raptors in passage over P. Tulai, and on occasions up to five species were seen simultaneously riding the thermals over the island. Of the Brahminy Kite, there were 3–4 individuals present on 3rd April, including at least one juvenile, but the population fluctuated irregularly and there is no certainty that all (or any) were resident on the island.

50/51. Accipiter sp. Goshawk.

Mid-morning 4th April, one large goshawk, distinctly streaked below (? *A. trivirgatus*, the Crested Goshawk) was riding one thermal over the island with a juvenile Brahminy Kite, while a Peregrine Falcon, a Sparrow Hawk, and two White-bellied Sea Eagles rode another. A little later five more goshawks passed over the island heading west, and in the late afternoon a flock of eleven was seen moving over. A flock of nine was observed in the early morning of 5th April.

52. Accipiter virgatus (Temminck). Sparrow Hawk.

A single Sparrow Hawk was recorded on 3, 4 and 5th April.

60. Haliaeetus leucogaster (Gmelin). White-bellied Sea Eagle.

At least two White-bellied Sea Eagles were present on the island; they were very active, calling frequently and flying into the trees. One bird was flushed from the ground on the western ridge of the island.

74. Falco peregrinus Tunstall. Peregrine Falcon.

On 4th April, see above.

128. Tringa hypoleucos Linn. Common Sandpiper.

Two birds present in the mangrove, 3rd and 4th April.

166. Treron vernans (Linn.). Pink-necked Green Pigeon.

A large flock roosting in the mangrove and feeding on the island was present on both visits. One male collected by B. Ensoll, 23rd April.

170. Ducula bicolor (Scopoli). Pied Imperial Pigeon.

Abundant, in large numbers in many parts of the island. A proportion left Tulai by day, flying to Tioman; but many remained on the island, feeding in noisy flocks in the tree tops along the ridge.

177. Chalcophaps indica (Linn.). Emerald Ground Dove.

One bird seen in the forest on the edge ridge.

?178. Caloenas nicobarica (Linn.). Nicobar Pigeon.

At 0620 hours, 5th April, in poor light, a large pigeon, appearing all black, was flushed from roost in the trees behind the camp.

197. Eudynamys scolopacea (Linn.). Koel.

On both visits Koels were abundant, in small flocks, creeping rather than flying about in the tree tops, calling noisily. A male and a female were collected on 3rd April. The former was in heavy moult, changing into nuptial plumage; the latter was not moulting.

231. Collocalia maxima Hume. Black-nest Swiftlet.

At least a thousand swiftlets congregated over the island each early morning of our visit (3–5th April), dispersing by day. Only *C. maxima* is resident on the island. Three breeding colonies are known, all in land-locked caves. We visited one site above Pasir Panjang, and found 278 nests in a clustered group attached to the sloping underside (c. 55° from vertical) of a large boulder; 24 nests were empty, 170 contained eggs (♀ 1) and 84 contained naked, newly-hatched nestlings (5th April).

239. Apus pacificus (Latham). Migratory Swift.

In small numbers over the island in the early mornings, flocking with *Collocalia*.

250. Alcedo atthis (Linn.). Common Kingfisher.

Observed both in the mangrove, and on the rocky shore on the north side of the island.

261. Halcyon chloris (Boddaert). White-collared Kingfisher.

Seen on the shore of camp bay.

526. Aplonis panayensis (Scopoli). Philippine Glossy Starling.

A flock feeding in high trees on the ridge on 4th April.

541. Nectarinia jugularis (Linn.). Yellow-breasted Sunbird.

Discounting the starlings, which were probably migrant, the Yellow-breasted Sunbird was the only passerine resident on Tulai. It was present only in the camp bay, where there was mangrove, and elsewhere on the island it was absent. Males were active, and a freshly made pendant nest, without eggs, was found on the edge of the mangrove on 4th April.

DISCUSSION

RESIDENTS

There are two ways in which the resident birds of Tioman could have populated the island. They could either represent a relict fauna, selected survivors from the late Pleistocene land mass that formerly connected all the major islands of the Sunda shelf; or they could constitute an oceanic fauna, a group of species that on different occasions and by different means have crossed the sea barrier between Malaya and Tioman. Support for the argument that the avifauna is relict is provided by the fact that, in the past, several taxonomists have considered that some

25 per cent of the island's known resident birds are subspecifically distinguishable from mainland forms, and that the affinities of these subspecies lie with populations further east on the Sunda shelf. However, the weight of evidence is otherwise.

In many ways more significant than the list of birds found on Tioman is the list of birds which are always conspicuous when present, by virtue of their size, habits or calls, and which, by their absence from the records, can certainly be excluded from the Tioman fauna. These certain absentees include a large number of birds that would be common in similar habitats on the Malayan mainland. At the family level, pheasants and partridges, parrots, hornbills, bee-eaters, and barbets are missing entirely. Despite the indeterminate taps heard in the region of Camp II, it is also unlikely that wood-peckers, most of which are noisy and conspicuous, are represented. It is improbable, too, that pittas, if present, could have been overlooked.

There are in addition a number of birds characteristically associated with particular habitats, which on the mainland are common and conspicuous in those habitats, but which on Tioman are lacking. One obvious group comprises the inland streamside birds, forktails, the bulbul *Pycnonotus zeylanicus*, forest kingfishers, the Black-and-crimson Broadbill *Cymbirhynchus macrorhynchos*. Also conspicuously missing are the spiderhunters, particularly *Arachnothera longirostris*, invariably associated with bananas on the mainland. Yet another group comprises open country and meadow birds, including the Yellow-vented Bulbul, the White-fronted Kingfisher, the resident pipit *Anthus novaseelandiae*, rice pests such as the weaver, the munias *Lonchura maja*, *L. punctulata* and *L. malacca*, and the Tree-sparrow. These birds, however, although accepted as native Malayan species, are geologically recent introductions to Malaya and are either, like the sparrow, directly symbiotic with man, or dependent on human activity, in felling and clearing the natural forest vegetation for the provision of a suitable habitat. *Lonchura striata* on the other hand is naturally a species of forest clearings and is probably a member of Malaya's anciently native avifauna. The isolation of Tioman has so far prevented any of the "new" land birds (except *Copsychus saularis* ?) from colonising the open habitat.

Other undoubtedly "old" species surprisingly absent from Tioman are tree swifts *Hemiprocne* spp., and the spinetail swift *Chaetura leucopygialis*, which are all common in lowland and submontane forest on the mainland. On Tioman there is a large resident population of the closely related swiflets *Collocalia*, which might have ousted other swifts by competition. However in several inland sites in similar forest in S.E. Asia (notably in Sarawak and Sabah) very much larger resident swiftlet populations coexist with the same species of *Hemiprocne* and *Chaetura*, providing evidence that swifts and swiftlets are not competitive to the extent of being exclusive.

In the list of absent species are included many of the larger forest birds (e.g. hornbills and pheasants). It is conceivable that after isolation by the rising sea, Tioman might have been too small to support a viable population of birds of this size. Until more is known of their ecology, this possibility must be kept in mind. However, it is known that Pulau Pangkor, Perak, supports a large population of Argus Pheasants. This island is, ecologically at least, probably sufficiently isolated

from the mainland to prevent recruitment of the population of a sedentary, relatively poor flyer such as the Argus. Since Pangkor is only a quarter the size of Tioman, it provides evidence that, other things being equal, Tioman is well above the viable size for a large forest gallinule.

Excepting *Napothera brevicaudata*, the birds of Tioman are predominantly common lowland forest species. Our observations indicate that despite reduced competition, no species has extended ecologically beyond the gross bounds of its normal habitat on the mainland. As a result many niches remain unfilled, and the visitor's first impression on Tioman is of the paucity of birds. This is particularly true on high ground above 2,500 ft., which is also the normal altitudinal limit to the range of most of these birds on the mainland. On Tioman too they do not extend beyond this limit, although the submontane species that on the mainland are competetive above this altitude are all lacking. Ornithologically, the peaks of P. Tioman are depressingly barren. The lack of montane forms is strong evidence that the bird population is not a relict fauna.

In the lowlands the paucity of species is compensated to some extent by the abundance of individuals. Many species (notably the Pink-necked Green Pigeon, the Green Imperial Pigeon, the Hill Myna and the Greater Racquet-tailed Drongo) are much more frequently encountered than they would be in similar terrain on the mainland. In lowland forest and plantation on Tioman, the total avian biomass is probably equivalent to that of the same habitat in the mainland. In open lowland scrub, and in submontane forest, birds are definitely scarcer on Tioman. These relationships are indicated by comparative netting figures in Table 2.

TABLE 2

Comparative netting figures on Pulau Tioman and in Selangor.

Habitat	Net-days	Catch (all species)	Birds per Net-days
PULAU TIOMAN			
(1) Hill forest, above 2,500 ft.	16	0	0
(2) Lowland forest, up to 1,100 ft.	9	4	0.44
(3) Overgrown plantation	7	5	0.71
SELANGOR*			
(1) Lowland forest (Subang)	1,800	924	0.51
(2) Overgrown plantation (Rantau Panjang) ...	4,500	3,684	0.81

*Figures for Selangor kindly supplied by Dr. H. E. McClure, U.S.A.M.R.U.

Unlike mammals, the total biomass of birds apparently nowhere on Tioman exceeds the biomass of an equivalent stretch of mainland forest. The extreme abundance of mammals has been attributed partly to the lack of mammalian predators. The relatively low bird population indicates the minor role mammalian carnivores play in controlling the population balance among birds. In part the failure of birds to attain such large numbers as mammals may be attributed to the presence of avian raptors, but to a great extent it is probably due to the ecological conservatism of birds and their consequent inability to expand into and exploit unoccupied ecological niches.

MIGRANTS

In March, on the mainland, many migrant birds are still to be found in the forest, particularly in high ground. The dearth of migratory passerines on Tioman stresses the fact that, on the northward movement at least, this island is right off the normal migration route. The only migratory passerines recorded (excluding Philippine Glossy Starlings, of doubtful status) were swallows, evidently wintering on Tioman, a poorly identified flycatcher, and the Yellow Wagtail. The behaviour of the wagtails suggested that all those seen were on passage, and were not a wintering population. In March, in Selangor, winter visitor Yellow Wagtails are still abundant in inland forest along stream-sides. On Tioman single bird(s) were seen only on the shore (probably one straggler); those in the flock were clearly on passage.

The shore itself, white coral sand meeting clear blue sea, is impoverished in comparison with the muddy flats of the west coast of Malaya, and inhospitable to waders. It is known that the principle northward route of migratory waders follows the west coast, and the paucity of this group on Tioman beaches was expected.

Other non-passerines of probably migrant status include several raptors, perhaps the Jambu Fruit Pigeon and the Broad-billed Roller. Little else can be added at present, except that it would be particularly rewarding to be able to compare bird lists of, say, June and November with our March and April list, in order to assess the true role of Tioman in bird migration.

PULAU TULAI

The most striking difference between the avifaunas of Tioman and Tulai was the abundance on the latter of characteristic island birds (notably the Pied Imperial Pigeon and the Koel) that were scarce or absent from Tioman. Characteristically, if not invariably, throughout its range the Pied Imperial Pigeon roosts on offshore islands, although frequently visiting the neighbouring mainland by day to feed. From both Tekek and Mokut flocks of this pigeon left at dusk to return to smaller islands (Tulai or P. Jahat) to roost and, although a proportion remained on Tioman, this island was evidently too large to be generally acceptable a roost. Similarly the Koel, although known from the coastal belt of the mainland, prefers small islands. In this case again Tioman was evidently too large to attract the Koels, even though they were abundant on nearby Tulai. In this context it is interesting to note the role of little P. Rengis, as a roosting site for large flocks of presumably non-breeding visitors — frigate-birds, swallows and starlings.

The Yellow-breasted Sunbird on Tulai strikingly illustrates the ecological conservatism of birds. Although no other small passerine was present, and although the flowerpecker niche was available over the whole island, the entire population of this species was restricted to the small area of fringing mangrove in the north-western bay.

SUMMARY

Records of 53 species of birds (excluding oceanic birds other than the frigates) from P. Tioman are discussed; and 21 species are recorded from Tulai. Eleven of the records from Tioman are apparently new. The possible origin of the resident avifauna of Tioman is examined, and it is concluded that it is derived from recent invaders from the mainland. The occurrence of migratory species on both islands is also discussed; and the differences between Tulai, a small island, and Tioman, a big island, are noted.

ACKNOWLEDGEMENTS

A large proportion of the notes and observations were made by Mr. D. R. Wells, who devoted most of his time on the island to study of the birds. Other notes (including 3 new records) are due to Dr. F. L. Dunn, who also surveyed the White-bellied Sea Eagle population on a two day boat trip round the island, and to other members of the party, as acknowledged in the text. I am grateful to all named for permission to use their material.

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5. The Reptiles

By J. R. HENDRICKSON

INTRODUCTION

EARLIER ZOOLOGICAL expeditions to Pulau Tioman have laid much stress on mammals and birds, but have resulted in few published accounts of the cold-blooded vertebrates occurring on the island. Smith (1930) records 12 species of lizards from Tioman, largely as a result of collections made in 1927 by Smedley of the Raffles Museum (now Singapore National Museum); Boulenger (1912) records one species of soft-shelled turtle; de Haas (1949) records one snake. I can find no other published records of reptiles from Tioman, and none whatever from Tulai.

The collections discussed below were made by Hendrickson in 1958, and by the University of Malaya party in 1962. Nine of the twelve lizards recorded by Smith are represented, as is the turtle recorded by Boulenger and the snake recorded by de Haas. The three lizard species recorded by Smith and not found by us are: *"Lygosoma"* (now *Leiolepisma*) *vittigerum* (Boulenger), *Mabuya longicaudata* (Hallowell), and *Goniocephalus harveyi* Boulenger. There is some room for doubt regarding each of these [13]. Six species of lizards and seven snakes, all represented by specimens now in the Zoology Department, University of Malaya, are here added to the list of reptiles known from Pulau Tioman. Several other species which were not collected, but are probably present, are mentioned below.

There are apparently no resident crocodilians on the islands. None of the islanders who were interviewed made any claim to ever having seen a crocodile there. Although there is no good reason why the Estuarine Crocodile, *Crocodylus porosus* Schneider, might not reach the island from time to time, the amount of available coastal swamp land is extremely limited and such areas enjoy little isolation from the human population.

The truly marine reptiles have not been given serious consideration in this report. There are an unknown number of species of sea snakes in the waters around the island and four species of sea turtles nest on the island beaches (investigation of these was the principal goal of the 1958 visit by Hendrickson). The Green Sea Turtle, *Chelonia mydas* Linn., nests on Tioman in the greatest numbers; smaller numbers of the Pacific Ridley, *Lepidochelys olivacea* (Esch.) visit the beaches; the islanders report sporadic nestings of the Leathery Turtle, *Dermochelys coriacea* (Linn.) and the Hawksbill, *Chelonia imbricata* (Linn.). There are apparently no terrestrial species on the island and the only non-marine chelonian found was the Soft-shelled Turtle, *Dogania subplana* (see discussion).

13. (*a*) *Leiolepisma vittigerum:* Smith (1930) states, "There is a specimen . . . from Pulau Tioman in the Raffles Museum." Despite a careful search of the collections now in the Museum, I have been unable to locate this specimen.

(*b*) *Mabuya longicaudata:* See text discussion of *M. multifasciata;* the only specimen of *longicaudata* now in the Singapore National Museum is from Thailand.

(*c*) *Goniocephalus harveyi:* There is one half-grown specimen of *G. chamaeliontinus* mislabelled *"Gonyocephalus herveyi"* (sic) in the Singapore National Museum (see text discussion of *chamaeliontinus*).

In addition to the 15 species of lizards collected and reported on here, mention should be made of two more which may well be added to the faunal list at some future date. The rocky coast of Tioman provides an extensive suitable habitat for one of the characteristic seashore skinks, such as *Emoia atrocostata,* and in 1958 I noted "small, black skinks" on the intertidal rocks when circumnavigating the island in a boat; the absence of this or a comparable species in our collections may be due to nothing more than insufficient collecting with a gun on the rocky portions of the coast. Secondly, I find it difficult to believe in the absence of *Varanus salvator;* this excellent swimmer, commonly found foraging on both rocky and sandy coasts, occurs almost ubiquitously on many small islands more isolated than Tioman. The locale and actions of a large varanid seen on Pulau Tulai (see below) fit this species. We collected no specimens, however, and I did not see any *Varanus* on the coast when circumnavigating the island in 1958.

Snakes, are, in general, much less conspicuous than lizards and our present list of eight species is probably far from complete[14]. Two species which were not collected but should eventually be added to the Tioman faunal list are the cobras, *Naja naja* (Linn.) and *Naja hannah* (Cantor). The islanders are uniformly familiar with both of these very distinctive and dangerous snakes, and all reports agree as to the presence of both on the island. During the 1962 expedition there were two meetings with Hamadryads, once by a party of two when rather full notes were taken. On one occasion during my 1958 visit I had a brief glimpse of the rear half of a jet black snake as it disappeared into a dense tangle of roots and debris; I believe this was a *Naja naja.*

On one occasion a party of three saw a small burrowing snake when they were digging out a rat's nest at the base of a palm in the forested uplands. This was described as 4″–5″ long, slim, and all black; it was assumed at the time to be a *Typhlops braminus.*

Only four species of lizards (no snakes or chelonians) were collected on Pulau Tulai — two skinks (*Mabuya multifasciata* and *Lygosoma scotophilum*) and two geckoes (*Cnemaspis kendalli* and *Cnemaspis* sp.). One member of the 1962 party reports seeing *Calotes cristatellus* and a large *Varanus.* The *Varanus* was seen on the rocky beach and ran into hiding among the rocks (see preceding discussion of *Varanus salvator*). This reduced fauna is in accord with the small size and depleted flora of the island (see description in Bullock and Medway, this *Bulletin,* p. 5).

Where possible, all the specimens collected have been compared with both published descriptions and specimens from the mainland of Malaya and Singapore. Where differences have been noted, these are described, but no new names have been added to the already confused taxonomy of South-East Asian reptiles. It is felt that the specimens available for comparison do not provide adequate coverage of the known museum material and that the literature should be searched more fully than is possible at this time. Almost certainly there are several definable new taxa represented in the Tioman collections, and I hope it will be possible to give these adequate treatment at some future date.

14. E. R. Alfred reports that *Maticora intestinalis* (Laur.) has been collected on Tioman since this ms. was first submitted.

SPECIES LIST

Dogania subplana (Geoffroy). Soft-shelled Turtle.

One specimen with a carapace about 20 cm. long was taken in the Sungei Ayer Besar near Camp II, Pulau Tioman, at about 1,000 feet elevation (see fig. 2). A smaller individual was taken in the lower reaches of the same stream near Kampong Tekek and others were seen at various points along this stream. The villagers at Kampong Juara say it is common there.

This species appears to be remarkable among Soft-shelled Turtles for its ability to invade the upper reaches of small hill streams. Downstream from Camp II where the 20 cm. specimen was found, the Sungei Ayer Besar descends the steep slopes of the island in repeated slides and falls as much as 10 to 30 feet high. I have found this same species in similar situations on the mainland, near the top of Kedah Peak and on Fraser's Hill, Pahang. It apparently occurs at all points on Tioman where there is sufficient surface water.

Boulenger (1912) records *Dogania subplana* from Pulau Tioman.

Varanus nebulosus (Gray). Clouded Monitor Lizard.

Four specimens (two adults and two juveniles) were collected on Pulau Tioman — all from Kampong Tekek and vicinity. A number of other individuals were seen at various points around the island on the coastal plain. This is a great tree climber, and our two adults were both shot out of the tops of coconut palms. We have only one sight record of *Varanus* from the interior uplands; although I see no reason why it may not occur there, it is likely that this lizard is more common near the cultivated areas where it finds a more plentiful supply of rats, nestling birds, and edible refuse. I have never seen this species prowling the intertidal rocks as does *Varanus salvator*.

This is apparently the first time that *Varanus nebulosus* has been reported from Pulau Tioman. The sight record of *Varanus* on Pulau Tulai (above) cannot be designated as to species; it may have been a *V. salvator*.

Cnemaspis kendalli (Gray). Slender-toed Forest Gecko.

Five specimens from Pulau Tioman and one (No. 5270) from Pulau Tulai are tentatively assigned to this species. They compare well with four specimens in my collections from the Malayan mainland. Of the six island specimens, one (No. 5276) is an adult female with two developing ova about 2.9 mm. in diameter; the remainder are males, apparently all adult although with testes of different sizes. The two smallest individuals are 51 mm. and the largest measures 53 mm. in snout-vent length.

In scalation these geckoes conform well with published descriptions of *kendalli* and differ from descriptions of other South-East Asian species (see following account of "*Cnemaspis* sp."). Boulenger (1912) gives 80 mm. as the snout-vent length of *kendalli*, but there seems to be room for doubt concerning this; Inger (pers. comm.) reports that the two type specimens of *kendalli* in the British Museum measure 56.1 and 60.9 mm. from snout to vent. Smith (1930) speaks of strongly expressed canthal ridges in *kendalli*, whereas in the present specimens the canthal ridges are very weakly expressed. No clear distinctions based on colour and pattern have been possible.

The state of our knowledge of the genus *Cnemaspis* is still very imperfect. Underwood's (1954) excellent review of the geckoes reserves the genus for further study and his following note in *Nature* (Underwood, 1955) goes no further than to definitely place the genus in his subfamily Gekkoninae. The following descriptive notes on the Tioman and Tulai animals should be considered along with the tentative species identification:

Digits slender, clawed, not dilated, with the two distal phalanges compressed and forming an angle with the basal portion. Underside of both basal and raised portions of digits with a row of transverse plates. Body moderately depressed and tail subcircular in section. Pupil round; brille of eye completely surrounded by a ridge of skin, least prominent postero-ventrally (somewhat more strongly expressed in these specimens than in the "*Cnemaspis* sp." to be described later). Forehead slightly concave; canthal ridges very faintly expressed. 11/12 upper and 10/11 lower enlarged labials. Ventral scales smooth; no preanal or femoral pores. Ventral side of tail with median series of large, keeled, semi-erect scales.

This smaller species differs markedly in ecology from the larger "*Cnemaspis* sp." taken on the same two islands, in that it frequents trees and dead wood rather than rock surfaces. So far as I can determine, all six of the present specimens were found well up off the ground in trees and were collected by shooting. The species appears to occur mainly in upland forests, but probably is limited more by its preferred tree habitat than by altitudinal factors. Smith (1930) records *Cnemaspis kendalli* from Pulau Tioman; whether the record stems from collection of these animals or the more conspicuous "*Cnemaspis* sp." cannot be determined.

Cnemaspis sp. Gecko

Twelve specimens from Pulau Tioman (8 males and 4 females) averaging 80.1 mm. in snout-vent length (min. 73 mm., max. 86 mm.), and one male from Pulau Tulai measuring 75.5 mm.

Boulenger (1912) records two species of "*Gonatodes*" (now *Cnemaspis* for Old-World species) from the Malay Peninsula: *kendalli*, which he describes as large with a snout-vent length of 80 mm. (but see earlier mention of measurements of type specimens in British Museum) and *affinis*, with a snout-vent length of 47 mm. Smith (1925) adds another small (42 mm. snout-vent length) species *siamensis* to the fauna of the Malay Peninsula and describes a large (75 mm. snout-vent length) species *nigridius* from Sarawak. The only other *Cnemaspis* species known to me from the general area is *C. boulengeri*, described by Strauch (1887) from Pulau Condore, South China Sea (= *Gonatodes glaucus* of Smith, 1921).

The Tioman and Tulai specimens are of the order of size of *kendalli* (Gray) as given by Boulenger, of *nigridius* (Smith), and of *boulengeri* Strauch. They are close to twice the size of *affinis* (Stoliczka) and *siamensis* (Smith) and they differ from each of these small species in a number of scale characters as well. They differ from *nigridius* and *boulengeri* in having neither femoral pores nor enlarged femoral scales, as well as showing other important differences in scalation. Unlike the descriptions of *kendalli* (and the smaller *Cnemaspis* from Tioman and Tulai which have been tentatively identified as *kendalli*), the present specimens have a median row of ventral caudal scales which lie flat, are not pointed, and have no keels.

The most that can be done at present is to describe the specimens at hand without assigning a species name to them:

Digits slender, clawed, not dilated; the two distal phalanges compressed, forming an angle with the basal portion, a row of transverse plates along the undersurface of both basal and raised portions. Body moderately depressed; tail subcircular in section, with ventral scales enlarged and in a median linear series on

at least the terminal $\frac{2}{3}$ of the tail in specimens with unregenerated tails (ventral scales irregularly arranged and not conspicuously enlarged at ventral tail base). Pupil round; brille of eye completely surrounded by a ridge of skin, this least prominent postero-ventrally. Forehead concave, snout rounded at the tip, its length almost twice the diameter of the eye; ear vertically oval, its distance from the eye about $1\frac{1}{4}$ times the eye diameter. Rostral quadrangular, entering the nostrils, deeply cleft in the midline; 10/13 upper and 10/11 lower enlarged labials; mental very large, broader than rostral, subtriangular, with one or two pairs of accompanying enlarged chin shields and — usually — a median unpaired shield behind the mental. Pointed, granular scales on the snout larger than those on the occiput; dorsum with small, granular scales intermixed with larger, conical, pointed tubercles, white in colour and arranged rather haphazardly in longitudinal rows. Ventral scales smooth, cycloid, not larger than the dorsal tubercles; no enlarged preanal or femoral scales and no preanal or femoral pores. Scales on ventral side of thigh smaller than on pubic area, tending to become granular; scales on ventral side of tibia larger than those on thigh, each with a small, clear keel; at distal extremity of tibia a variable group of as many as 6 to 8 enlarged scales from two to three times the size of their neighbours, arranged in an elongate group rather than in a single line (ref. *boulengeri*), extending as much as 1/5 of the distance up the tibia.

Colour (in alcohol) variable gray, symmetrically blotched with both darker and lighter areas, but not usually much conspicuous contrast. Principal series of median dark blotches begins anteriorly with a dark crescent leading from each eye around to the nape, with an unpaired dark blotch between these in the midline. Following this, a pair of slanting dark bars in front of the shoulders. The mid-dorsal dark markings continue posteriorly with three pairs of elongate dark blotches on the trunk, a pair of subcircular dark blotches over the sacrum, and a similar postsacral pair. There may be a matching secondary series of smaller dark blotches lateral to the three large markings on the trunk. Lighter areas tend to form narrow, irregular cross bands immediately posterior to each set of dorsal dark markings. The venter is variably dusky, always with the mid-ventral area of the trunk and the ventral surface of the thighs lighter.

The single specimen (No. 5271) from Pulau Tulai is conspicuously lighter in colour than any of the Tioman specimens. It follows the pattern of pigment distribution described above, but it is so light in ground colour that the "lighter" blotches are barely detectable. On this specimen the larger tubercles on the dorsal skin are very much less developed than on any of the Tioman specimens and the digits appear to be shorter; the first fingers of this 75.5 mm. specimen measure about 6.2 and 6.3 mm. (from junction of first and second fingers to tip of claw of first finger), while the first fingers of a 73 mm. Tioman specimen measure about 6.8 and 6.9 mm.

One of the Tioman females had no enlarged ova; two had each a pair of developing, spherical ova, 5.2 mm. and 6.9 mm. in diameter. The fourth female contained one large, shelled egg which measured approximately 12.6 mm. in diameter.

This species is more a frequenter of rock surfaces than of trees. All seven specimens which I collected in 1958 were found at night clinging to the undersides of large boulders where these were piled up off the ground; two of the 1962 specimens from the slopes of Gunong Kajang bear the notation "on rock". The species apparently occurs through nearly the entire altitudinal range of the island, wherever it finds its preferred rock-face habitat; it seems to be much more common within the upland forest than on the sea coast.

Hemidactylus frenatus Dumeril & Bibron. House Gecko.

One specimen (No. 5286) was taken in the Rest House at Kampong Tekek. This is an adult female, measuring 50 mm. snout-vent length; it contains two oviducal eggs, each over 5 mm. in average diameter. It conforms well with published descriptions and with specimens from other parts of Malaya.

This is the commonest house gecko of the Malay Peninsula and I have never failed to find it wherever there are human habitations, from city office buildings to remote kampongs and on boats. I have also collected it in the forest, but rarely. The presence of a single specimen in the Tioman collections should not be taken as any sign of its rarity on the island — I have full confidence that it occurs in virtually every dwelling place on the island. I doubt, however, that it occurs in any numbers in the upland forest of Tioman.

There is little point in debating whether this species has been introduced to the island by man, or formed part of the fauna before man arrived on the island. In this part of the world it is almost as consistent a companion of human societies as are cockroaches and lice over most of the world; if it was not present on the island earlier it would dependably have been one of the very first human introductions.

This is apparently the first time the species has been recorded from Tioman.

Gehyra mutilata (Weigmann). House Gecko.

Two specimens: No. 5269, an adult male 51 mm. in snout-vent length from the Rest House at Kampong Tekek, and No. 5264, an adult female (no large ova) 49 mm. in snout-vent length, from a dwelling in Kampong Mokut.

These specimens agree well with Boulenger's (1912) description (less well with the description in Smith (1935) which covers a wider geographic range and gives higher counts for labials, subdigital lamellae, and preanal and femoral pores)

Although both the specimens from Tioman were collected in houses, this species also inhabits trees and rock faces. While a very likely prospect for introduction by man, it is less completely tied to human habitation and easier to visualize as a natural inhabitant of the island before the advent of man.

This is apparently the first time the species has been recorded from Pulau Tioman.

Draco melanopogon Boulenger. Flying Lizard.

Seventeen specimens from Pulau Tioman, all but one collected along the trail crossing the island between Kampong Tekek and Kampong Juara, mostly around 1,000 feet above sea level. One individual was taken on the slopes of Gunong Kajang at 2,700 feet. There are ten adult males and one half-grown male; the remaining six individuals are adult females, four of them with large eggs.

The Tioman specimens correspond with descriptions in Boulenger (1912) and Taylor (1958), aside from being slightly larger and having somewhat larger heads. In this they appear to differ also from mainland specimens, but measurements of the small sample available did not show differences which fully met tests of statistical significance.

The four gravid females each contained two elongate shelled eggs. These were all about the same size and averaged 14 mm. along the axis by 6.5 mm. in greatest diameter. Ten individuals randomly selected from among the gravid females in a large Selangor collection and opened for inspection also each had two eggs. One Tioman female had an egg partially extruded into the cloaca (ready to lay?),

the remaining oviducal egg in this individual was dissected out for examination and found to measure 15.7 mm. along the long axis by 7.6 mm. in diameter. The eggs were all distinctly pointed at each end. Figure 4 compares the eggs of *melanopogon* with those of *Draco volans* (see discussion of that species).

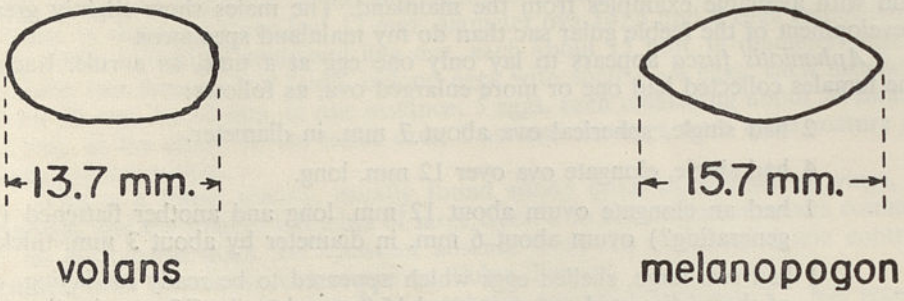

Figure 4. Eggs of *Draco* species.

This is a true forest animal, and I did not record it from the vicinity of villages; all our specimens were collected in undisturbed forest. In this restriction it conforms well with the habits of the species on the mainland, where it is usually the commonest species of *Draco* in undisturbed areas. A large collection of over 400 *Draco* made from primary forest near Kuala Lumpur by a resident tribe of aborigines was more than 80% *melanopogon* (see also discussion of *Draco volans*).

Smith (1930) records this species from Pulau Tioman.

Draco volans Linnaeus. Flying Lizard.

Five individuals, all from Kampong Tekek, Pulau Tioman. Three were adult males and two were adult females (one gravid).

The specimens all conform well with Boulenger's (1912) description and with the mainland specimens available.

The gravid female in this Tioman collection had four large eggs (about 12.5 mm. x 7.5 mm. diameter). Flower (1896) also records four eggs. Of some twenty gravid females and clutches of eggs I have examined in Singapore, most have had four and none have had less than three eggs. It is interesting to note this normal number of four eggs in contrast to the usual two eggs of *Draco melanopogon* (see discussion under that species). The eggs of *volans* also differ markedly in shape from *melanopongon* eggs, the former being smoothly rounded at the ends instead of pointed (fig. 4); my notes give measurements of 13.7 mm. in long diameter by 7.6 mm. in short diameter for *volans* eggs freshly laid, and 14 mm. x 7.8 mm. for an egg the day before it hatched.

This is a species of open plantations and parkland more than of true forest. On Tioman it is probably restricted to the developed areas around villages on the coastal plain. Boulenger (1912) says, "specially abundant in coconut plantations on the islands near the East Coast of the Peninsula". In Singapore it is particularly abundant in the older residential areas which have a park-like environment with scattered trees planted in the gardens. In Selangor I have collected the species in a city park, but a collection of over 400 *Draco* made from nearby primary forest by a resident tribe of aborigines, and including eight different species, had no *Draco volans*.

Smith (1930) records this species from Pulau Tioman.

Aphaniotis fusca Peters. Earless Agama.

Thirteen specimens from Pulau Tioman, five adult males and eight adult females. All but one were taken in undisturbed forest along the trail crossing the island between Kampong Tekek and Kampong Juara.

The Tioman individuals compare well with Boulenger's (1912) description and with available examples from the mainland. The males show slightly greater development of the feeble gular sac than do my mainland specimens.

Aphaniotis fusca appears to lay only one egg at a time, as a rule. Each of the females collected had one or more enlarged ova, as follows:

2 had single, spherical ova about 7 mm. in diameter.

4 had single, elongate ova over 12 mm. long.

1 had an elongate ovum about 12 mm. long and another flattened (degenerating?) ovum about 6 mm. in diameter by about 3 mm. thick.

1 had two large, shelled eggs which appeared to be ready for laying; one of these, dissected out, measured 15.9 mm. long by 7.3 mm. in diameter. The eggs were smoothly rounded on the ends, as in *Draco volans* (fig. 4), but were more elongate.

One suspects that when two ova are formed and grow simultaneously, there is a tendency for one to be depressed and to degenerate after the ratio of total egg volume to body cavity size reaches a certain critical level.

This species is characteristic of undisturbed forest. It is not common anywhere on the mainland, so far as I am aware. I have four specimens collected on the Peninsula over a period of some eight years, yet I have no doubt that I could collect 20 or more individuals in one concentrated day on Pulau Tioman, where it may be continually encountered during a walk through the forested uplands. The reasons for its abundance on Tioman are not completely clear, but I am inclined to believe this is due to the absence of one or more critical predators.

Aphaniotis shares with *Draco melanopogon* a general foraging habitat on the stems of forest trees. There is apparently almost no overlap in diet between the two species (see Bullock, this *Bulletin* p. 93, on stomach contents), but there may be competition for space. The following appears in my field notes for 1st June, 1958 (vicinity of 1962 party's Camp II):

> "One (*Aphaniotis*) was recognized only after it had been shot down, along with a *Draco*, from about thirty feet up on the trunk of a very large strangling fig (the two had appeared to be both *Draco*, engaged in some sort of social play; they were first seen about 18″ apart)."

On two other occasions I saw *Draco melanopogon* and *Aphaniotis fusca* in close proximity on tree trunks and obviously engaging each other's attention. In each case the *Draco* was the more active of the two and appeared to be defending a territory; in each case the *Aphaniotis* appeared to give way.

Smith (1930) records this species from Pulau Tioman.

Goniocephalus chamaeleontinus (Laurenti). Anglehead.

Eleven specimens from Pulau Tioman, all adult, 3 males and 8 females. All were collected in the forested uplands between Kampong Tekek and Kampong Juara, most along the trail leading across the island between the two villages.

The Tioman individuals agree quite well with Smith's (1930) description, written when he recorded the collection of a specimen from Pulau Tioman and added this species to the Malayan faunal list. I do not find the third finger to be shorter than the second as Smith says (the two are equal in length). The colour

in alchohol (and in life, as I recall it) has a definite bluish cast, particularly on the nuchal and dorsal crests. Smith says the species had previously been recorded from the Mentawi Islands, Sumatra, Java, and the Natunas; his record is the first from Malaya, and Tioman apparently remains the only Malayan locality where it is known to occur.

Seven of the females contained enlarged ova (the eighth had been shot at close range and had most of the abdomen destroyed). One had 6 ova, each about 10 mm. in diameter, three had 12 mm. diameter ova (4, 5 and 6 eggs respectively), and a fifth individual contained five ova, each about 15 mm. in diameter. The remaining two females had large, oblong eggs with shells — 4 eggs, each measuring about 21 mm. by 12 mm. in one instance; 5 eggs, each measuring about 24 mm. by 12 mm. in the other. In the latter case, I assume the eggs were quite mature and ready for deposition.

This is a forest species, usually found sitting quite motionless on vines, tall saplings, and the smaller branches of large trees. I do not believe it occurs commonly on the coastal plain. Its apparent absence from the mainland fauna contrasts strongly with its relative abundance on Pulau Tioman.

Smith (1930) reports that *Goniocephalus harveyi* Boulenger "... has recently been obtained on Pulau Tioman." It is not clear whether Smith himself examined a specimen of *harveyi* from Tioman, or whether he merely recorded an identification made by someone else. Despite assiduous searching in both 1958 and 1962 which produced numbers of the other species of *Goniocephalus*, we failed to find *harveyi* on Pulau Tioman. In the Singapore National Museum is a half-grown (80 mm. snout-vent length) specimen of *G. chamaeleontinus* which bears the label: "*Gonyocephalus herveyi* (sic); Tioman Id., S. China Sea; vi, 1916; C.B.K." On these grounds I suggest that Smith's record is based on a mis-identified specimen and the species *harveyi* should be dropped from the Tioman faunal lists.

Goniocephalus grandis (Gray). Anglehead.

Fifteen specimens from Pulau Tioman, including five males (one juvenile) and ten females (two sub-adult); all were collected from the upland forest between Kampong Tekek and Kampong Juara except for one individual which was taken on the forest edge of Kampong Tekek itself (elevation about 200 feet). Smith (1930) records the species from Tioman.

These animals are easy enough to identify with Boulenger's (1912) description when a series such as this is available. I would be very doubtful of my ability to identify a lone female specimen from this description. The sexual dimorphism in this species exceeds anything I have heretofore seen in agamid lizards, and warrants further description.

The males are conspicuous by their very high, sail-like nuchal and dorsal crests of joined scales. They are larger than the females, my four adult males averaging 148 mm. in snout-vent length (min. 145, max. 154 mm.) as compared with an average 125 mm. snout-vent length for my eight adult females (min. 120 mm., max. 133 mm.). Their colour (in alcohol) ranges from olive brown to metallic green and blue dorsally, with a scattering of round yellow to orange spots on the flanks. The colour grades to light greys and off-whites ventrally; there is a course vermiculation of blue-grey lines faintly visible on the throat. The tympanum is dark with a contrasting light spot where the extra-columella joins the membrane. The tail bears from ten to twelve dark (brown to black) cross bands which are wider than the intervening bands of contrasting lighter colour. The limbs are also cross-banded dorsally, the dark bands being from two to three times as wide as the intervening light spaces.

The females possess only the merest vestiges of the nuchal and dorsal crests which are so large in adult males; the juvenile male, 72 mm. in snout-vent length, already has a delicate, low dorsal crest which is better developed than in the adult females, where this structure is virtually non-existent. Both females and young are contrastingly marked with a complex pattern of stripes in dark brown and light tan or cream, giving a drastically different appearance from that of the adult males. The dorsal surface of the snout is mostly dark brown with a few lighter lines; on each upper eyelid are five light lines, the central one extending straight across the interorbital space to join its fellow of the opposite side to form a bar across the head; the two light lines anterior and the two posterior to this do not ordinarily meet across the interorbital space, but commonly join at their inner ends to form a "V" or "U" with its opening laterally; the anteriormost and posteriormost of these finger lines ordinarily delimit the upper lid. On the nape is a large, dark, triangular area with a central light spot; it includes practically all of the small, low nuchal crest and might be characterized as a dark chevron, beginning on each occiput and pointing backward; a contrasting light chevron (one end at each eye corner) separates this from a following heavy, dark chevron over the pectoral area (one end at the postero-ventral border of each eye). The pattern continues posteriorly with three dark chevrons on the trunk, one on the sacral region, and one post-sacral marking, then is carried on to the tail by the pattern of banding which was described for the male. The intervening light areas which separate the dark chevrons on the trunk and sacral areas contain central thin, dark lines. With progression posteriorly, there is a tendency for the outer ends of the chevron markings to be diverted backward, producing roughly an "M" shape in the last two or three when viewed from above and behind. The flanks and limbs show approximately the same pattern as on the adult males, but rendered in contrasting rich brown and light tan or cream rather than in the olive grey and yellow or orange shown by the males. The throat bears a number of thin, dark lines which join here and there to form a longitudinally-oriented reticulum, comparable to that shown in adult males, but clear and contrasting.

The juvenile male (No. 5243) has the full "female" colouration. It has identifiable testes, however, and (as stated above) the secondary sexual character of the dorsal crest has already begun to be expressed.

I have been able to compare the Tioman individuals with only two specimens from the mainland, a small male (115 mm. snout-vent length) from Johore and a larger male (145 mm. snout-vent length) from Selangor. Both of these have large testes and are fully mature. The Tioman males appear to have relatively shorter, higher nuchal crests than the mainland specimens. Both the Selangor and Johore specimens have 29 points (individual scale tips) in the nuchal crest; the Tioman males have 23, 24 25, and 27 points. The basal portions of the nuchal crests are covered by ancillary series of enlarged scales, considerably larger than the ordinary scales on the dorsal surface of the neck; anteriorly these are arranged in somewhat confused fashion, but from about the middle of the crest on posteriorly they form regular rows. At the level of the tenth principal scale forward from the rear end of the nuchal crest, there are three series of these ancillary scales in the two mainland specimens, four series in the Tioman males. The Johore specimen has a relatively low crest which is probably not fully developed and therefore not suitable for comparison, but the Selangor animal can presumably be taken as fully developed; at the level of the tenth main scale forward from the rear of the crest, the distance from the scale point to the base of the crest is 17.6 mm. in the Selangor specimen, 18.9 mm., 20.1 mm., 20.8 mm., and 21.7 mm. in the Tioman males.

My mainland specimens are so badly faded that comparison of colour patterns is almost impossible. It can be noted, however, that both mainland animals show narrow dark and broad light bands on the limbs (the reverse of the pattern in the Tioman specimens — see above).

The two smallest Tioman females (99 mm. and 111 mm. snout-vent length) have no large ova, but each of the other eight females contains large ova as tabulated below (Table 1).

All the oviducal eggs had firm shells and appeared ready for deposition. They had evenly-rounded ends; the measurements given in Table 1 show the length along the long axis and the diameter at the midpoint.

TABLE 1

Ova in female *Goniocephalus grandis* from Tioman

Specimen	*No. of ova*	*Size, etc.*
5291	5	8 mm. (ovarian)
3006	3	11 mm. (ovarian)
5238	3	12 mm. (ovarian)
3061	2	12 mm. (ovarian)
3039	3	21 × 10 mm. (oviducal)
3060	3	22 × 10 mm. (oviducal)
5239	2	26 × 11 mm. (oviducal)
5290	4	22 × 11 mm. (oviducal)

This is a forest lizard, but it appears to be most common on Tioman in the vicinity of the boulder-strewn stream courses. It does not appear to occur on the coastal plain. So far as I can determine, all the males were found in trees, but many of the females were first seen moving on large boulders in stream beds. Following is an extract from my field notes (of 2nd June, 1958):

> "One of the large specimens was collected from the trunk of a streamside tree, about 8 feet up on a 2′ diameter trunk. All the others were shot on large boulders in the stream bed. In each case, my attention was drawn to the animals by their movement rather than purely on the basis of form (as is usually the case with most of the large *Goniocephalus*). These lizards are very long-legged and agile; they ran and jumped rapidly across the broken stream bed. All six, including the one taken on the tree, were found in portions of the stream bed filled with large boulders (a person could not walk easily along, but had to clamber over boulders or jump from one to another). In all these places the tree cover was more sparse than in other stretches, and during the middle of the day it was drier and sunnier than along much of the rest of the course of the stream."

Members of the 1962 expedition report that on more than one occasion they disturbed females which escaped by diving into the water of the Sungei Ayer Besar and disappearing beneath the surface.

Goniocephalus armatus (Gray). Horned Anglehead.

Three specimens from Pulau Tioman, an adult male (116 mm. snout-vent length) and two adult females (109 mm. and 120 mm. snout-vent length). These agree fairly well with Boulenger's (1912) description (of "*Acanthosaura armata*"). They differ from Smith's (1935) key and description in that they do have a perceptible small gular pouch (as do also my specimens from the nearby mainland). Both descriptions state that the gular scales are smaller than the ventrals, but this is not the case with the scales on the median portion of the gular sac in the three Tioman animals.

When compared with mainland specimens from Johore and Pahang, the Tioman animals appear to have heavier heads and relatively larger tympani, but Smith (1935) notes that there is considerable variation in head proportions in this species. The mainland specimens have virtually continuous nuchal and dorsal crests, whereas there is a clear, but very short, break between the two in all of the Tioman animals. Further, the mainland specimens conform with the published descriptions in having all the gular scales much smaller than the ventral scales (see above).

The larger of the two females from Tioman has 10 spherical ova which average about 10 mm. in diameter. The smaller female has 8 large, shelled oviducal eggs from 18 mm. long and averaging about 10 mm. in diameter. These appear to be ready for deposition.

This species is another inhabitant of the wooded uplands. All three of our specimens were taken along the trail which crosses the island between Kampong Tekek and Kampong Juara. They seem to prefer fairly dense undergrowth and apparently spend much of their time on the ground; one of our specimens was found under a dead log.

Smith (1930) records this species from Pulau Tioman.

Calotes cristatellus (Kuhl). Variable Lizard.

Five specimens from Pulau Tioman, 4 adult males and 1 female with two eggs about 8 mm. in diameter. Three were collected at Kampong Tekek and one at Kampong Mokut; only one was taken in undisturbed forest, near Camp II. Medway contributed a sight record of this species from Pulau Tulai (above).

The Tioman animals agree well with the description in Boulenger (1912) and Smith (1935) and with specimens from various parts of the mainland. The account in Smith (1935) includes the statement: "Eggs oval, 30 by 11 mm. in size." This is not the case with the eggs I have seen in Singapore, Selangor, and Pahang, where the eggs are elongate and fusiform with "puckered", tapering tips (cf. Kopstein, 1938, plate XXVI, figures 65 & 66 — photographs of the eggs of *Calotes jubatus* Dumeril & Bibron). An egg shell from which I hatched a young *Calotes cristatellus* in Singapore measures 40 mm. from tip to tip, by 9.7 mm. in diameter. Its axis is slightly curved.

Calotes cristatellus appears to be more of an inhabitant of dense, brushy vegetation than of undisturbed, high forest. It is particularly common around towns in hedges and shrubbery. On Pulau Tioman it appears to be much more common in the disturbed areas around human habitations (4 of our 5 specimens came from such areas) than in the relatively undisturbed uplands, where it is largely confined to stream courses, land slips, and similar sites where the vegetation is lower and more dense.

This species is common throughout the southern portion of the Malay Peninsula, but this is apparently the first record of its occurrence on Pulau Tioman.

Mabuya multifasciata (Kuhl). Common Malayan Sun Lizard.

Eight specimens (four of each sex) from Pulau Tioman and two specimens (a male and a female) from Pulau Tulai. They agree in most particulars with descriptions in Boulenger (1912) and Smith (1935), and with mainland specimens of this species. No particular differences were noted between the Tioman and Tulai animals.

Two of the females had only small ova; one had 4 large, shelled oviducal eggs with well-developed embryos, and the remaining two females each contained 5 advanced embryos enclosed in transparent membranes and with depleted yolk sacs. These last embryos appeared about ready for birth.

This is an active, very abundant ground lizard, to be heard scuffling in the leaf litter in practically all forested parts of the island during the day (and, less commonly, the night). All our specimens were taken in the wooded uplands, mostly along the trail which crosses the island between Kampong Tekek and Kampong Juara. I did not record it as common in the vicinity of villages on the coastal plain, where *Dasia olivacea* (although much less abundant) appeared to more or less replace it.

Smith (1930) states that *Mabuya longicaudata* ". . . has been met with on Pulau Tioman." He does not record *Mabuya multifasciata* as present on the island, although we found it to be the most abundant ground lizard there. We did not collect any *Mabuya longicaudata*. I find it difficult to believe that the skinks accounting for Smith's record and our *multifasciata* skinks are not the same. It is perhaps worth noting that Smith says *longicaudata* has been "met with"; he does not say it has been "obtained", or that a specimen is in Raffles Museum "from Tioman", as he does for most of the other Tioman records in this 1930 account. This leaves the possibility that Smith's statement might have been based on a sight record only.

Two of our eight specimens from Tioman have narrow, longitudinal black lines dorsally, as Boulenger (1912) describes for *"siamensis"* (= *longicaudata*) and as Smith (1935) describes for *longicaudata*. On field sighting alone, this pattern might well be sufficient to cause identification as *longicaudata;* such a pattern is not recorded by either author for *multifasciata*. However, comparison of the Tioman specimens in hand with descriptions and with mainland specimens of both *multifasciata* and *longicaudata* reveals the following:

(1) The Tioman animals agree with *multifasciata* in having the tail about $1\frac{1}{2}$ times as long as the body rather than nearly or quite twice the body length, as in *longicaudata*.

(2) They all agree with *multifasciata* in having conspicuously tricarinate scales and 3 or 4 small lobules on the anterior edge of the ear opening (*longicaudata* usually has 2 keels on the dorsal scales and 3 or no keels on the lateral scales; it usually has no small lobules on the anterior edge of the ear opening).

(3) They agree with *multifasciata* in having 31 or 32 scale rows around the body (Smith, 1935, gives 30–34 rows for *multifasciata* and 26–30 for *longicaudata*).

(4) They agree with *multifasciata* in having 18 or 19 *obtusely keeled* lamellae under the fourth toe (Smith, 1935, says "17 to 23"), rather than with *longicaudata* which has 22 to 27 smooth lamellae under the fourth toe.

(5) All ten Tioman specimens have numbers of black-edged white spots on the flanks, as described by Smith (1935) for *multifasciata;* such spots are not obvious on *longicaudata*.

I feel quite definite about the identity of our Tioman specimens being *multifasciata*, and suggest that the record of *longicaudata* on the island should be considered as dubious until substantiated by further specimens collected there.

Dasia olivacea Gray. Tree Skink.

Five specimens, 3 males and 2 females, all from Kampong Tekek, Pulau Tioman. Both females are under 100 mm. in snout-vent length and have only small ova in the ovary.

The Tioman specimens agree well with the descriptions in Boulenger (1912) and Smith (1935). I have two mainland specimens for comparison, one from Rompin, Pahang (50–60 airline miles from Tioman), the other from the National Park in north-east Pahang. The Rompin specimen resembles the Tioman animals closely in colour and pattern, having a bright blue-green venter and lateral black dots with white flashes, arranged in transverse bars and tending to extend across the bronze-brown dorsal surface; the National Park specimen is a uniform dark olive-brown, shading to gray ventrally, and has only the very faintest hint of dark lateral dots.

This is a skink of semi-arboreal habits. It appears to occur mainly on the coastal plain of Tioman, where it largely replaces the upland *multifasciata*. *Dasia olivacea* appears to be much less abundant in its lowland habitat than is *Mabuya multifasciata* in the upland forest.

Smith (1935) says: "More than most skinks, *D. olivacea* appears to have a preference for small islands." Smith (1930) records this species from Pulau Tioman.

Lygosoma scotophilum Boulenger. Supple Rock Skink.

Six specimens, all males, from Pulau Tioman and one gravid female from Pulau Tulai. The female contains two large, shelled eggs in the left oviduct; these have been pierced by shot and are collapsed, but probably measured about 10 to 11 mm. long by about 5 to 6 mm. in diameter when intact. All individuals compare well with the description of this species in Boulenger (1912).

This is a small, rock-inhabiting species occurring quite commonly wherever there are large masses of bare rock, either on the sea coast or along stream courses in the uplands. Most of our specimens were collected along the course of the Sungei Ayer Besar in stretches of the stream bed jumbled with boulders the size of small houses. The animals were usually seen moving, gecko-like, over smooth, vertical or overhanging faces of the large, water-worn boulders, more often in the shade than in the sun. Their movements are quick and frequent, and they apparently have acute vision; small movements on the part of an observer some 20 feet away were usually sufficient to cause the lizards to flick out of sight into dark crevices in the rocks. Much of their foraging is apparently carried on deep down in debris-filled crevices between the boulders. Only about half of those shot could be retrieved, the others being lost when they fell into inaccessible crevices.

Smith (1930) has reported this species from Pulau Tioman.

The Snakes Collected on Pulau Tioman[15]

Snakes are, in general, much less conspicuous than lizards and our present collections from Tioman are less likely to include a meaningful representation of the ophidian fauna than is the case with the lizards. It is also much more difficult to define the habits and environmental preferences of most snakes, and no attempt has been made here to give our collections much ecological or zoogeographical meaning.

Except for a record of *Natrix chrysarga* (de Haas, 1949), I can find no published records of snakes from Tioman; apparently the other seven species listed here are recorded from the island for the first time. (Also, see my Introduction for discussion of cobra species on the island).

15. Common names taken from Tweedie, 1957.

Python reticulatus (Schneider). Reticulated Python.

One juvenile specimen taken at Kampong Tekek in 1962 and one 8 foot individual taken in 1958. The latter was found coiled up on a small beach at the back of a sea cave on a headland immediately north of Telok Dungun; its stomach contained a partly-digested mouse-deer (*Tragulus napu*). I believe the Reticulated Python to be quite common on Tioman, and to constitute one of the major predators on the island.

Natrix chrysarga (Schlegel). Speckle-bellied Keelback.

One specimen, collected in the forest behind Kampong Juara. This is a common snake with a wide range on the mainland. It is known to climb trees and bushes and to feed on lizards.

de Haas (1949) includes Pulau Tioman in the distribution of this species.

Oligodon purpurascens (Schlegel). Brown Kukri Snake.

One specimen, found in Ulu Lalang. It is more pale than mainland specimens in my collection, and the head pattern differs from that figured by Tweedie (1957) in that the longitudinal dark marking on the head does not join with the transverse bar between the eyes to form a "T" shape. This is a common snake on the mainland, usually found in wooded country.

Oligodon signatus (Gunther). Barred Kukri Snake.

One specimen was collected near Camp V, at about 2,700 feet elevation. Tweedie (1957) says this is a rare snake; he says there are a number of records from Singapore and reports one specimen taken in Malacca and another in Negri Sembilan.

Liopeltis tricolor (Schlegel).

One specimen, collected in the vicinity of Camp II (in 1958), when it fell from a tree branch about 20 feet overhead. The genus is poorly known, but considered to be a jungle group.

Calamaria vermiformis (Dumeril & Bibron). Variable Reed Snake.

One specimen, found on the trail between Kampong Tekek and Camp II at an elevation of about 500 feet. The colour pattern of this individual is that of the "lowland" form described by Tweedie (1957), except that it lacks the speckling or suffusion with black on the light portions of its venter which Tweedie describes for the specimens from under 3,000 feet elevation. In this it resembles another lowland specimen I have from Kelantan. On the mainland this snake is found mainly in foot-hill jungle.

Cerberus rhynchops (Schneider). Dog-faced Water Snake.

Two specimens, one from Kampong Tekek and one from Kampong Lalang. Perhaps the commonest Malayan water snake, this species is apparently abundant in the slow-moving and stagnant waters of the coastal plain on Tioman. It freely enters tidal waters.

Dryophis prasinus Boie. Grass-green Whip Snake.

Three specimens, all collected in the forest in the vicinity of Camp II. It is probable that this snake is plentiful on Tioman; the unusual abundance of small, arboreal lizards, which form the main food of *Dryophis*, would correlate with this.

DISCUSSION

Pulau Tioman is notable for the abundance of lizards found there, both in terms of the numbers of species and the numbers of individuals of many of the species. Particularly in the case of the arboreal agamids, the species biomass on Pulau Tioman appears to be many times greater than on the adjacent Malayan mainland. This can most readily be attributed to the paucity of mammalian and avian predators (see Medway, this *Bulletin,* on mammals and on birds), freeing the lizard populations from principal limiting factors which operate on the mainland allowing them to expand to new limits which are imposed by other factors such as competition for space or, possibly, food. Even the principal groups of lizard-eating snakes appear to be absent from the island; the Vine Snake, *Dryophis prasinus,* is the only important lizard predator among the snakes collected.

Each lizard species occupies approximately the same ecological niche as it does on the mainland and there are few obvious major lizard niches left unfilled on the island. *Varanus salvator* probably does occur on the island, although we did not collect a specimen; this would fill the role of the large-sized seashore scavenger. The apparent absence of any large species of the genus *Gecko* would indicate that there is a "vacancy" for a large-sized, nocturnal predator on the stems of the forest trees.

I attribute the absence of crocodilians to the lack of sufficient coastal swamp habitat on Tioman. This argument of insufficient habitat does not apply in the case of non-marine chelonians, where the existence of only a single species of Soft-shelled Turtle leaves a number of niches unfilled. It seems certain that a good habitat exists for several terrestrial tortoises and terrapins in the forested portions of the island, but they are apparently all absent. *Geomyda spinosa* occurs on the Natunas Islands, according to de Rooij (1915); it is difficult to understand why this common forest species and/or other species are absent from Pulau Tioman, so much less distinctly isolated than are the Natunas. In the absence of competition, *Dogania subplana* has taken over all the available freshwater habitat on the island; it was found not only in the small upland streams which are apparently typical for it, but also in the semi-stagnant waters of the coastal swamps — a habitat more likely to be inhabited by a *Trionyx* species on the adjacent mainland.

In the case of the snakes, it is difficult to be as confident of the adequacy of our sample of the fauna as in the case of lizards and chelonians. However, the evidence at hand indicates a depleted ophidian fauna. Four of the ten species listed are medium-to-small ground snakes; there are two water snakes — one a freshwater inhabitant and the other (*Cerberus rhynchops*) characteristically living in brackish to salt waters. *Python reticulatus* is probably one of the island's most important predators on small mammals (see Medway, this *Bulletin,* p. 27). The single arboreal snake, *Dryophis prasinus,* and two (uncollected) cobras complete the list. If all the large, active, terrestrial genera of colubrid snakes such as *Elaphe, Zaocys, Ptyas,* etc., are truly absent, one is prompted to wonder how the ophiphagous *Naja hannah* makes its living in the absence of the main items on its usual mainland diet.

As with the mammals and birds (see Medway), it is interesting to consider the reptile fauna in relation to the history of Tioman in general — to what extent they may be a relict collection isolated from the rest of ancient Sundaland by rising postglacial seas, and to what extent they may be more recent immigrants, whether by human agency or not.

Table 2 lists the 26 reptile species collected on Tioman and indicates the known distribution of each species. Eliminating the un-named species of *Cnemaspis*, the remaining 25 species all—without exception—occur also on one or more of the Sunda Islands. 24 occur on the Malay Peninsula as well (*Goniocephalus chamaeliontinus* gets no closer than Tioman), but only 15 of the 25 species occur on the mainland of Asia above the Malay Peninsula. This indicates a principal affinity of the Tioman fauna with the Sunda fauna rather than with the Indo-Chinese complex. I believe it argues for consideration of the Tioman fauna as principally a relict isolated *in situ* rather than a collection of immigrants across the water from the mainland.

TABLE 2

Tioman Reptile Species* — Distributional Data

Continental = occurs on the main continent of Asia above the Malay Peninsula.
Peninsular = occurs on the Malay Peninsula (Thai or Malayan portions).
Sunda = occurs on one or more islands of the archipelago related to ancient Sundaland (Borneo, Sumatra, Java, etc.)

	Continental	*Penisular*	*Sunda*	
Chelonians				
Dogania subplana	x	x	x	? marine immigrant
Lizards				
Varanus nebulosus	x	x	x	
Cnemaspis kendalli	–	x	x	
Cnemaspis sp.	?–	x	?–	
Hemidactylus frenatus ...	x	x	x	? introduced by man
Gehyra mutilata	x	x	x	? introduced by man
Draco melanopogon	–	x	x	
Draco volans	–	x	x	
Aphaniotis fusca	–	x	x	
Calotes cristatellus	x	x	x	
Goniocephalus armatus ...	x	x	x	
Goniocephalus grandis ...	–	x	x	
Goniocephalus chamaeleontinus ...	–	x	x	
Mabuya multifasciata ...	x	x	x	
Lygosoma scotophilum ...	–	x	x	
Dasia olivacea	x	x	x	
Snakes				
Python reticulatus	x	x	x	? marine immigrant
Oligodon purpuracens ...	x	x	x	
Oligodon signatus	–	x	x	
Calamaria vermiformis ...	–	x	x	
Liopeltis tricolor	–	x	x	
Natrix chrysarga	x	x	x	
Cerberus rhynchops	x	x	x	
Dryophis prasinus	x	x	x	
Naja naja	x	x	x	
Naja hannah	x	x	x	

*The three lizard species reported by Smith (1930), are omitted from this list to avoid confusion (see footnote 13, p. 53). The two cobra species (not collected) are included, but other "probables" such as *Varanus salvator* are omitted.

That at least some of the Tioman species are immigrants seems quite logical, and certain ones appear more likely than others to have been able to reach the island after its final isolation by rising seas. The large Pahang River, which drains a vast area in Malaya, debouches on the East Coast where the set of the currents is such as would carry vegetation-rafts southward toward Tioman. It is possible to believe in the likelihood of *Dogania subplana, Python reticulatus,* and *Cerberus rhynchops* successfully swimming the 24 miles from the mainland to Tioman (the distance might have been considerably less in earlier times). In my opinion, it is more probable than not that, even if the two house geckoes *Hemidactylus frenatus* and *Gehyra mutilata* were not already on Tioman, they would have arrived there in human baggage during the last 100 years. The skinks *Mabuya multifasciata* and *Dasia olivacea* are very widespread and appear to have a marked facility for island-hopping; I am quite prepared to believe that the coconut-plantation-inhabiting *Draco volans* was transported to Tioman by human agents—most probably as eggs carried with soil around the bases of plants which were dug up and brought to the island for transplanting. If the above turtle, 2 snakes, and 5 lizards are subtracted from the list of 25 species, the fauna score then becomes 100% shared with Sunda Islands, 94% shared with the Malay Peninsula, and only 47% shared with Asia above the Peninsula. Having granted the most probable immigrants after Tioman was isolated as an island, the remaining argument is strong for relict derivation.

In my mind's eye I visualize the Tioman mass as an isolated small mountain in a low, swampy Sundaland, grading from a poorly-drained base up through well-drained slopes to a virtually barren, excessively well-drained peak region consisting of little more than a colossal heap of boulders and supporting only meagre vegetation. Although its upper levels approached the required elevation above sea level, I do not believe Tioman supported many of the high-altitude species which existed — and have survived — in other, better-vegetation, high regions of Sundaland. During the fluctuation of sea level which took place during Pleistocene times, I visualize the resident fauna on the slopes of Tioman retreating uphill and returning down, losing some species during the periods of stress when the rising water level forced terrestrial species into the more limited space and more difficult living conditions which would exist on the upper, more rapidly-drained slopes. At some times the sea level was higher than it is now, as evidenced by fossil coral reef formations on the island today. (There seems to be no evidence of very recent uplift or subsidence of the land itself.)

During the periods of most extreme stress, the tropical rain forest as we know it in Malaya today must have virtually disappeared on Tioman except for relatively small, isolated pockets where soil and drainage were favourable for survival. Many plant species must have died out (see remarks on dipterocarps, etc., in Bullock and Medway, this *Bulletin,* p. 6) and many vertebrate species must have disappeared as their habitat altered. The terrestrial chelonians may have been forced out by disappearance of food in the form of fruits of tree species which did not survive and fungi which no longer had appropriate damp shade in the altered forest remnants. The insect-eating lizards, however, might have best survived these periods of trial, as indicated by their relatively abundant species representation on the island today.

Following the times of worst trial, conditions have presumably improved and a steady process of soil-building has gone on, so that today — with the most pressing predators removed and with considerable good habitat available — the surviving reptilian species have reached a high level of density.

It is interesting to contrast the Natunas Islands with Tioman. The former are very much more isolated and have a geographically very much stronger argument for relict derivation of their fauna than does Tioman. They differ in having a good deal more high ground capable of supporting good forest, and they presumably offered more abundant and more congenial refuge for relict species retreating uphill ahead of the rising Pleistocene waters. The number of species in the Natunas reptile fauna is probably about twice that of Tioman; 16 of the 25 listed Tioman species have been recorded from the Natunas, more may well occur there. There are 3 non-marine chelonians in addition to *Dogania subplana*, one (*Geomyda spinosa*) fully terrestrial forest species and two freshwater terrapins. The Natunas fauna has 6 *Draco* species as against Tioman's 2, and two lizard genera (*Japalura* and *Tachydromus*) which have not been found on Tioman.

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6. The Amphibians

By J. R. HENDRICKSON

INTRODUCTION

IT APPEARS that previous zoological collectors on Pulau Tioman have paid little attention to the amphibians. This is apparently the first faunistic account dealing with the amphibians of the island; so far as can be determined, all species except *Rana macrodon* (reported by Smedley, 1931) are here recorded from Tioman for the first time.

The collections reported on here were made by Hendrickson from 26th May to 5th June, 1958 (during the course of a visit made primarily to survey sea turtle nesting beaches) and the University of Malaya party in March and April, 1962. The 1958 collections were made at Kampong Tekek and Kampong Juara, and along the trail which runs across the island to connect the two villages. The 1962 party explored more fully and penetrated much difficult terrain beyond this area; all of the frogs collected from above 1,500 feet elevation were taken by the later expedition.

Twelve species, one described as new, are represented in the present collections. No doubt further exploration will demonstrate the existence of other species of amphibians, unrecorded here. However, I believe that the main body of the amphibian fauna is now known and that a fair faunistic summary can be made. Further new records will probably be confined mainly to small, relatively inconspicuous species which are closely tied to restricted niches in the forested interior of the island. I would, for instance, expect further intensive work in the island streams to produce a caecilian.

One major service which future expeditions can perform is to give special attention to investigation of the abundance and distribution of *Bufo parvus* and *Rhacophorus leucomystax* on the island. Both these species are characteristically abundant and conspicuous wherever they occur on the adjacent Malayan mainland, yet our present collections contain only a single specimen of each. If they exist at all as breeding populations, many specimens should have been found. It is quite anomalous to have each species represented by a single individual after such intensive collecting as was done on the 1962 visit. I believe that, should future expeditions fail to find more of these two amphibians, they should be dropped from the faunal list and our two individuals considered as chance introductions, without opportunity to breed.

No amphibians were found on Pulau Tulai. There is no permanent freshwater on that island (see Bullock and Medway, this *Bulletin*, p. 7).

SPECIES LIST[16]

Megophrys monticola nasuta (Schlegel). Nose-horned Frog.

Four specimens were collected, including 2 adult females, 1 adult male, and 1 immature individual. One of the adult females contained ova about 3 mm. in diameter; the gonads of the other appeared to be inactive.

16. Established common names do not exist for most Malayan frogs. For the sake of consistency, an attempt has been made here to suggest English names for most species; these should not be considered as necessarily having wide acceptance and usage.

Comparison with specimens from Singapore, Selangor and various parts of Pahang (including the Rompin area, about 50–60 airline miles from Tioman) revealed no particular differences between Tioman and mainland forms. I follow Inger (1954) in considering *nasuta* Schlegel as a subspecies of *monticola* Kuhl and van Hasselt.

All four of these specimens were collected in wooded portions of the island, the male at an elevation of about 200 feet behind Kampong Mokut, one large female on the cross-island trail behind Kampong Tekek at an elevation of about 900 feet, and the other large female and the immature individual on the slopes of Gunong Kajang, at about 2,500 feet. This species was commonly heard calling along the Sungei Ayer Besar near Camp II.

Bufo parvus Boulenger. Forest Ground Toad.

A single specimen of this (usually) common little forest toad was taken at Kampong Juara on 26th March, 1962. It is an adult female (No. 5092) with many large ova; snout-vent length, 45.7 mm. When compared with specimens from Selangor, Pahang and Kelantan it shows no remarkable differences except for possibly having slightly higher, sharper spines on its tubercles.

When the writer visited Tioman for eleven days in 1958, he did not see or hear a single *Bufo*. The 6 persons in the main party on the 1962 expedition did considerable collecting for 43 days, covering many parts of the island, and they did a great deal of searching for amphibians. One might have expected one or more species of *Bufo* to be quite common, yet only this single specimen was taken and no larvae were recorded. This must remain a mystery for the present — one is tempted to suggest that we may have collected an individual recently introduced from the mainland.

Pelophryne signata (Boulenger). Dwarf Toad. (Plate 9).

Eight specimens, all females, of this interesting little toad were collected.

Barbour (1938) lists eight species of *Pelophryne*. Of these, my specimens fit best the descriptions of *signata* from Borneo (Boulenger, 1894) and *brevipes* from the Philippines (see Inger, 1954 and 1960a). Both of these species have a more or less cruciform dorsal pattern and venters spotted with black, and both are of comparable small size to the Tioman specimens (Boulenger's report on the two known specimens of *signata* gives 15 mm. snout-vent length; Inger records a mean of about 17.1 mm. for *brevipes*). The sizes of the eight Tioman specimens are as follows:

No. 5306 (immature)	10.3 mm. snout-vent length
No. 5222 (immature)	11.3 mm. snout-vent length
No. 5223 (subadult female)	16.0 mm. snout-vent length
No. 5221 (subadult female)	16.1 mm. snout-vent length
No. 5224 (adult female, ova = 0.8 mm.)[17]	18.6 mm. snout-vent length
No. 5178 (adult female, ova = 0.9 mm.)[17]	18.9 mm. snout-vent length
No. 5115 (adult female, ova = 1.0 mm.)[17]	20.0 mm. snout-vent length
No. 5116 (adult female, ova = 1.5 mm.)[17]	20.3 mm. snout-vent length

The Tioman specimens have the tympanum bare and very distinct, $\frac{2}{3}$ to $\frac{3}{4}$ the diameter of the eye, as described for *signata* (Boulenger, 1894). It is not covered with skin and obscure, slightly less than $\frac{1}{2}$ the diameter of the eye as described for *brevipes* (Inger, 1954). The hands are less extensively webbed (particularly on the medial side of the second finger) than Inger's (1954) figure of *brevipes*. In this they

17. All frogs possessing enlarged eggs had these in one ovary only, the other ovary appearing inactive.

appear to match Boulenger's original figure of *signata* (*Proc. Zool. Soc. London*, 1894, pl. 40, fig. 1). It should be mentioned that, while Boulenger states in the original description that the tibiotarsal articulation reaches the tip of the snout, it extends only to the front of the eye in these specimens.

The colour and pattern of these little toads is sufficiently striking to warrant an attempt at description : Dark blackish brown dorsally with a variably contrasting large "X" pattern formed by lighter bands which run from each upper eyelid back across the body to the inguinal region of the opposite side, the point of intersection of these bands being a short distance behind the level of insertion of the forelimbs. At the point of intersection of the "X" and also over the coccyx are two fairly extensive spots of guanistic overlay. When the "X" pattern is dark and relatively inconspicuous, the large guanistic spots are very intense and contrasting; when the "X" is a contrasting light tan (as on all the smaller specimens), the guanistic spots are suppressed. The dark ground colour is intensified to a contrasting black on the edges of whichever light pattern is dominant. There is a dark interorbital bar and variably-expressed dark median line from the snout tip back to this. The tops of many of the tubercles on the dorsal surface are a bright carmine, particularly in the dark areas, producing further colourful contrast. The limbs are blotchily barred with darker colour. There is a fairly sharp line of demarcation between dorsal dark ground colour and ventral chrome yellow, irregularly blotched with black; this line runs from just below the center of the tympanum (which is uniform brown) back to the hind limb base. There are irregular black blotches on the yellow venter (heavier in the larger specimens) tending to increase to a marbling of black on the throat and decreasing to a faint speckling on the ventral thighs.

Plate 9 shows five specimens arranged to show the variation in dorsal pattern.

All the specimens were taken in forest on the higher parts of the island: five along the trail crossing the island from Tekek to Juara — minimum elevation 900 feet, two at Ulu Lalang above 2,400 feet, and one on Gunong Kajang above 2,900 feet. All were collected during the daytime, by insect collectors. They were sitting on the ground or a few inches up off the ground in the herb layer of the forest vegetation. They were not found in any particular relation to water; in this they conform with other observations on the ecology of the genus, which is apparently a highly adapted general forest type, able to breed in very small, inconspicuous bodies of entrapped rain water (Inger, 1960a).

Ansonia tiomanica sp. nov. Slender Toad. (Plate 10).

Two specimens, an adult male (No. 5129) and an adult female with eggs (No. 5128), are described here as syntypes. Both were collected by Bullock and Medway from a cave at an elevation of about 2,400 feet, Ulu Lalang, Pulau Tioman, Pahang, Malaya, on 5th April, 1962. The types are deposited in the Bishop Museum, Honolulu.

Diagnosis[18]: A medium-sized species (female 36.3 mm. and male 31.2 mm. in snout-vent length); tympanum clearly visible externally; finger tips broadened into small spatulate disks; first finger not reaching to disk of second finger; no interorbital ridges or conspicuously enlarged tubercles in interorbital space; at least two phalanges of third and fifth toes free of web; no tarsal ridge; uniform dark blackish brown with scattering of small, irregular yellow dots.

Further description : Habitus slender, with long legs, the tibiotarsal articulation reaching the front of the eye and the tarso-metatarsal articulation extending well out beyond the snout. Snout about as long as the eye, constricted in front

18. In describing this new species I have attempted to follow the form of presentation used by Inger (1960b) in his review of the genus *Ansonia*.

of the eyes and sloping in profile, truncate and projecting; canthus rostralis distinct, sharp; lores vertical, faintly concave; interorbital space at narrowest point about $1\frac{1}{4}$ times upper eyelid; tympanum diameter slightly less than $\frac{1}{2}$ that of eye.

Fingers long and slender, with tips expanded into bluntly rounded, spatulate disks which, on at least fingers 3 and 4, are twice as wide as the narrowest portion of the digits which bear them. Inconspicuous web at base of fingers, not reaching beyond distal ends of basal phalanges. Length of first finger (measured from median edge of palmar tubercle) about equal to diameter of eye in male, slightly greater than diameter of eye in female. First finger not reaching disk of second, which in turn does not extend as far as the base of the disk of the fourth finger. Subarticular tubercles feeble; a distinct, rounded outer palmar tubercle (fig. 5A).

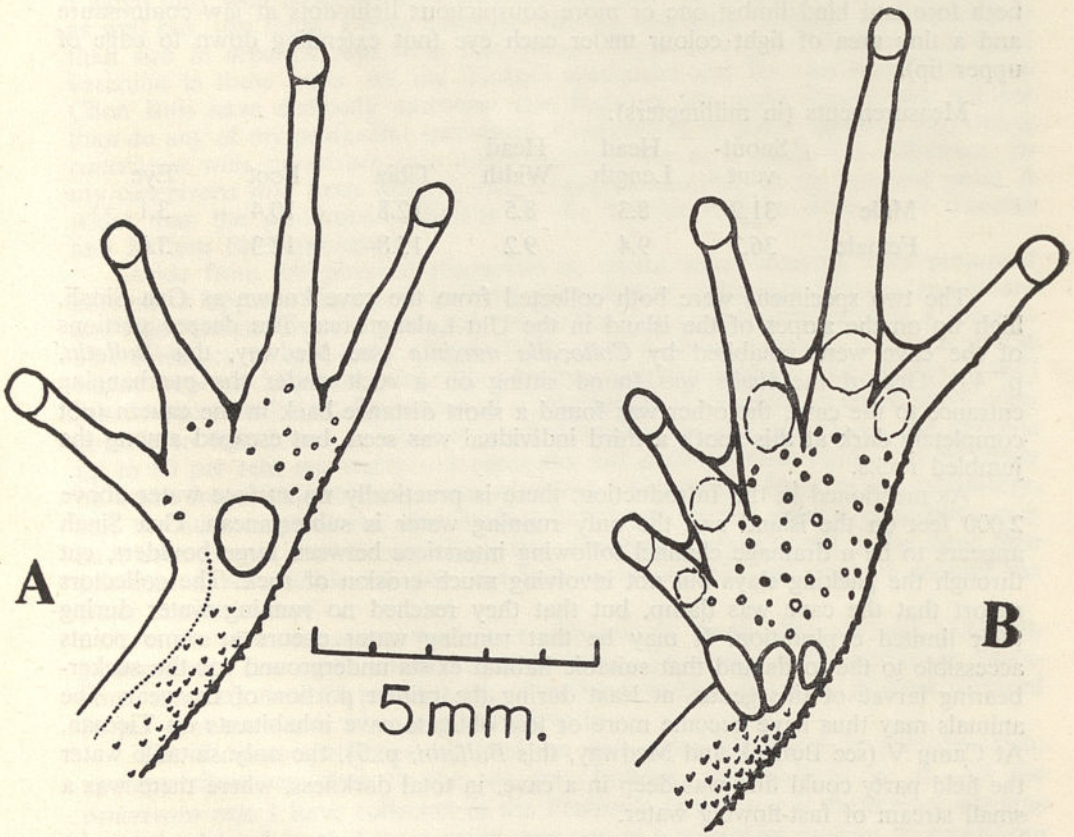

Figure 5. *Ansonia tiomanica.* A, male, palmer surface of left hand; B, female, palmer surface of left foot.

Toes with very slightly expanded disks (not as large as disks on fingers); third toe shorter than fifth (not reaching level of base of fifth toe disk in male, reaching this level in female); reduced web on foot, extending narrowly out along sides of toes but leaving at least two phalanges free on third and fifth toes, three phalanges free on fourth toe. Subarticular tubercles weak to nearly absent; outer metatarsal tubercle oval, well-demarcated and moderately high; inner metatarsal tubercle large, very flat, tending to be divided into an inner, more flattened tubercle and a central, oval, slightly higher tubercle which almost touches the medial edge of the outer tubercle. No sign of a tarsal ridge (fig. 5B).

Densely covered dorsally with heterogeneous rough tubercles, lower and smoother on head, more spinose on back, smaller-sized on limbs, grading to granular texture on ventral surfaces.

Male (which has large, lobulated testes) with longitudinal slit on right side opening into vocal sac; no noticeable nuptial pad and no particular distinctive tubercles or asperities under mandible. The larger of the ova carried by the female were about 1.5 mm. in diameter; all ova were unpigmented (Plate 10).

Colour (in alcohol) uniform dark blackish brown grading to grey ventrally, with sparse scattering of round dots (single tubercles) and small irregular spots (groups of tubercles) of yellowish white (reported by the collectors as canary yellow in life), tending to form ill-defined narrow bands of contrasting colour on both fore and hind limbs; one or more conspicuous light dots at jaw commissure and a tiny area of light colour under each eye (not extending down to edge of upper lip).

Measurements (in millimeters):

	Snout-vent	Head Length	Head Width	Tibia	Foot	Eye
Male	31.2	8.3	8.5	12.8	10.4	3.1
Female	36.3	9.4	9.2	15.8	12.3	3.6

The two specimens were both collected from the cave known as Gua Sinah, high up on the slopes of the island in the Ulu Lalang area. The deeper portions of the cave were inhabited by *Collocalia maxima* (see Medway, this *Bulletin*, p. 43). One of the toads was found sitting on a rock under the overhanging entrance to the cave, the other was found a short distance back in the cavern (not completely dark at this spot); a third individual was seen, but escaped among the jumbled rocks.

As mentioned in the Introduction, there is practically no surface water above 2,000 feet on the island and the only running water is subterranean. Gua Sinah appears to be a drainage channel following interstices between large boulders, cut through the packing clays but not involving much erosion of rock. The collectors report that the cave was damp, but that they reached no running water during their limited exploration. It may be that running water occurs at some points accessible to the toads and that suitable habitat exists underground for the sucker-bearing larvae of this genus, at least during the rainier portion of the year. The animals may thus have become more or less obligate cave inhabitants on Tioman. At Camp V (see Bullock and Medway, this *Bulletin*, p. 7), the only suitable water the field party could find was deep in a cave, in total darkness, where there was a small stream of fast-flowing water.

Rana cancrivora cancrivora Gravenhorst. Crab-eating Frog.

Seven specimens : adult male (No. 5100) from Kampong Lalang; three sub-adult females from Kampong Tekek; three immature specimens from about ½ mile south of Kampong Tekek. All were collected in or near standing or very slow-moving water in stream meanders near sea level.

The Tioman specimens conform with descriptions of the species *cancrivora* (Boulenger, 1920; Smith, 1930 (key); Inger, 1954). They resemble two specimens in my collection from Chon Buri, Thailand but differ from all my Malayan and Singapore specimens in their smaller size, as indicated by the adult male (and not contra-indicated by the three sub-adult females). Smith (1930) described southern

Thai frogs from the vicinity of Patani as a new subspecies, *Rana cancrivora raja*, on the basis of their larger size. He cites snout-vent lengths of 60 mm. (male) and 73 mm. (female) for Bangkok specimens of his "forma typica" (= *cancrivora cancrivora*) as against 87 mm. (male) and 120 mm. (female) for *cancrivora raja*[19]. The adult male from Tioman measures only 61 mm. from snout to vent, whereas among some 15 adult males from Selangor and Singapore, none measure less than 71 mm. It seems probable that Smith's 87 mm. male and 120 mm. female *cancrivora raja* were his largest specimens; my largest specimens (from Selangor) measure 81 mm. (male) and 118 mm. (female).

Size alone seems an unsatisfactory criterion for separating off subspecies; I agree fully with other workers who feel that the two subspecies "look different" as well but, like them, I have failed to turn up any good physical character other than size to separate *raja* from *cancrivora*. There is a great deal of individual variation in these frogs. All my Tioman specimens and the two specimens from Chon Buri have distinctly narrower skin flaps on the outer side of the 5th toe than do any of my peninsular specimens. Comparison of larger series of *cancrivora cancrivora* with *cancrivora raja* might validate this as a distinctive difference. In my *cancrivora raja* from Malaya and Singapore this flap at its broadest point is wider than the penultimate phalanx of the 5th toe (not so with the 7 Tioman and 2 Chon Buri specimens).

Aside from the physical characters so useful when working with preserved animals, it appears there is a marked physiological difference between *cancrivora* and *raja*. The northern, smaller subspecies has long been known to show a remarkable tolerance to salt water (Inger, 1954, gives a short summary of some of the earlier reports). Recent work by Gordon, Schmidt-Nielsen and Kelley (1961) has demonstrated that, by means of a physiological uraemia in some ways comparable to that found in elasmobranch fishes, *cancrivora cancrivora* can tolerate up to 80 per cent sea water — 3 times the salt concentration which can be borne by other frogs. This tolerance was observed with starved frogs in the laboratory, and the authors point out that feeding individuals under natural conditions may have even greater salt tolerance than they observed. Larvae tested at the same time tolerated a remarkable 3.9 per cent salinity (about 120 per cent of normal sea water concentration).

At the time the above work was going on in South Vietnam and Thailand, I attempted a few crude tests on *cancrivora raja* purchased in the market in Singapore; some survived 25 per cent sea water for two days, but none of these survived 50 per cent sea water when transferred to it.

The Tioman specimens reported on here were all found in semi-brackish, swampy situations close to the sea (see Bullock, this *Bulletin*, p. 4). All the *cancrivora raja* I have collected in the Peninsula have been in freshwater swamps beyond tidal influence. I have never seen one in a mangrove swamp, as *cancrivora cancrivora* has been reported.

The salt tolerance of the Tioman *cancrivora* should be tested. This could be a factor in explaining the existence of this "Thai" subspecies on the island, while subspecies *raja* holds sway on the mainland. It is interesting to speculate on a vast Sundaland population of *cancrivora* being subjected to salt water invasion during the Pleistocene, with strong selection pressure for salt tolerance, and successful adaptation occurring and persisting to the present in areas as far apart as Thailand and Java, with a minor pocket at Pulau Tioman.

19. Inger (pers comm.) reports that specimens of *cancrivora* from Borneo range from 51.0 to 70.9 mm. snout-vent in males and 52.9 to 82.0 mm. snout-vent in females, roughly comparing in size with northern (coastal) Thai, Tioman, and Java specimens.

Rana blythii (Boulenger).[20] Malayan Giant Frog.

44 specimens from Tioman are at hand, 19 adult males, 13 adult females, and 12 immatures and juveniles of various sizes. The ten largest males (measured to the nearest 0.5 mm.) average 108.4 mm. in snout-vent length (min. 96 mm., max. 117.5 mm.); the ten largest females average 86.1 mm. (min. 81.0 mm., max. 95.0 mm.). They conform to Boulenger's (1920) description of his "variety *blythii*" in shape of head, size of eye, and generally greyish olive colouration. Six of the females have large unpigmented ova from 2.1 mm. to 2.5 mm. in diameter; one of these (No. 5175) has the ova in oviducal sacs, with full jelly coats, immediately ready for laying.

Comparison with other specimens from many parts of Malaya, including the Rompin area of Pahang (50–60 airline miles from Tioman) fails to reveal any distinctive differences on the part of the Tioman specimens. None are as large as the largest mainland specimens, but they are not significantly smaller than the mass of breeding individuals obtained from the same localities. Note might be made here of a suspected distinctiveness in the call of *blythii* from Pulau Tioman. When I visited the island in 1958 I thought that I had identified the call of Singapore *blythii* as a muffled, fairly musical grunt. Although I was never able to actually see an individual as it called, I had repeatedly located large *blythii* as a result of tracing this particular sound. On Tioman I was able to observe individuals in the act of calling; there, the call sounds remarkably like the imitation of flatulence which can be made by expressing air in a short burst through tightly compressed lips.

Inger (pers. comm.) points out that *blythii* of the Malay Peninsula and Borneo differs from *macrodon* and from Philippine taxa (*acanthi, magna, macrocephala,* and *visayanus*) in that *blythii* lacks vocal sacs and has eggs without a densely pigmented dark hemisphere. I have no quarrel with this, but wish to add a word of caution to anyone opening Malayan *blythii* for a quick look at the ova as an aid to identification. The ova of *blythii* are not formed of contrasting dark and light hemispheres, but neither are they completely pigment free as are the ova of, say, *Staurois larutensis* or *Rhacophorus leucomystax*. When a little less than 1 mm. in diameter they gain considerable pigment and become dark grey *all over;* as they grow further, this pigment is diffused and they become progressively lighter in colour, although they never become as pale as the pigment-free eggs of the above species. If a female opened for inspection happens to have no large eggs, but has a developing size class of ova which have reached the most heavily pigmented stage, their dark grey contrasts with the white of the many tiny ova to produce an impression of speckling which at first glance might be mistaken for the characteristic appearance of an ovary with black-and-white eggs.

Rana blythii is a forest frog, inhabiting the vicinity of moving water for the most part. It is definitely the dominant amphibian on Tioman, living mainly in forest near upland streams, but also following these down onto the edges of the coastal plain. At night, individuals sit at the edge of the water, or back on a raised bank as much as ten feet or more from the water, seizing any moving object of the appropriate size class. Mainland individuals have been found with frogs, rats and snakes in their stomachs, in addition to invertebrates.

As noted in the introductory remarks, this frog has been recorded from Tioman by Smedley (1931).

20. Inger (in litt.) establishes *blythii* as a full-standing species. I agree with this and therefore, with Inger's permission, use the name here rather than "*macrodon* Dumeril & Bibron" or "*macrodon* var. *blythii* Boulenger".

Rana (Discodeles/Platymantis) sp.

Two male specimens, 34.0 and 20.8 mm. in snout-vent length, collected at about 1,000 feet on the cross-island trail and at 2,500–3,000 feet in Ulu Lalang. These frogs are unidentifiable to species by any literature or specimens available to me. They have disks on the fingers with circummarginal grooves separating dorsal and ventral surfaces. They lack any intercalary cartilages between ultimate and penultimate phalanges. The outer metatarsals are partially bound together by heavy skin. The omosternum is distinctly forked at the base and has a bony style. There are small, but strong, vomerine teeth.

Boulenger (1918a, 1918b and 1920), while recognising close affinities, kept the genera *Cornufer* and *Platymantis* separate from *Rana* on the basis of large disks with a ventral transverse groove in the former and reduced webbing on the foot in the latter. He recognised a subgenus *Discodeles* of *Rana* which shares with *Cornufer* and *Platymantis* all the characters listed in the preceding paragraph, but which differs from them in having no ventral transverse grooves on the disks and in having strongly webbed feet. *Discodeles* also has a large, retractile papilla in the middle of the tongue which the others lack. Van Kampen (1923) recognised *Cornufer* as generically distinct on the basis of its highly differentiated digital pads (adhesive portion demarcated by the ventral transverse groove); he treated both *Discodeles* and *Platymantis* as subgenera of *Rana*. Smith (1930) states that he has "taken full advantage" of Boulenger's 1920 monograph, but classes as *Discodeles* two species (*tasanae* and *tenasserimensis*) which conform to *Platymantis* in having reduced webs and no tongue papillae; he gives no discussion of this; he did not deal with *Cornufer* or *Platymantis* species in this work. Noble (1931) viewed *Discodeles, Platymantis* and *Cornufer* each as full genera separate from *Rana*. Inger (1954) did not deal with species of *Discodeles*, but combined *Platymantis* and *Cornufer* species into the single genus *Cornufer*, separate from *Rana*.

The specimens concerned here (No. 5117 and 5176) differ from *Discodeles* in having reduced webbing on the feet and no tongue papillae. They differ from *tasanae* and *tenasserimensis* (*Discodeles* of Smith, 1930) in vomerine teeth, size of disks, webbing of foot, colouration and other characters. They differ from the *Cornufer* of Boulenger, Van Kampen and Noble in having only small digital disks and in lacking any transverse ventral grooves on these; and they differ from Inger's concept of *Cornufer* in having the outer metatarsals less fully bound together (groove separating fourth and fifth metatarsals ends about $\frac{1}{2}$ way back dorsally, about $\frac{2}{3}$ of the way back ventrally) : they also lack the supernumerary subarticular tubercle on the fourth finger which Inger describes for Philippine species of *Cornufer*. They most nearly conform with *Platymantis* of Boulenger (derived from and with affinities to species of his subgenus *Discodeles*) or with Smith's *Discodeles* as exemplified by *tasanae* and *tenasserimensis*.

The interesting feature of this record is that, aside from *Rana tasanae* Smith from South Thailand near the Kra Isthmus and *Rana tenasserimensis* Sclater from Southern Burma and the northern part of the Malay Peninsula, this is the only other record known of a frog of this facies intermediate between the *Discodeles* species of South India and the species of *Discodeles* and *Platymantis* of the Philippines, Melanesia, and New Guinea.

The specimens are of superficially unremarkable appearance, dark blackish brown dorsally, grading to grey-brown on the limbs; one has a contrasting dirty-white mid-dorsal stripe with a fine dark line down its center, the smaller specimen lacks this; the limbs bear partial bars of black; ventrally the colour is off-white with sparse, very fine brown speckling on the throat. The smaller specimen was found on the cross-island trail between Camp II and Juara; the larger was found on the forest floor high up on the slopes of the island at Ulu Lalang, far from any known surface water (frogs of this group are known or suspected to be terrestrial breeders, passing the larval stage in the egg membranes). Neither specimen has vocal sac openings, or any sign of nuptial pads.

Rana erythraea (Schlegel).

39 specimens : 4 females (3 with large eggs), 20 males, and 15 immatures and juveniles. Comparison with specimens from Singapore, South Pahang, Selangor and other parts of Malaya revealed no particular differences on the part of the Tioman individuals.

All the specimens were taken in or near water on the coastal plain, where the water of debouching streams is either slow-moving or impounded and stagnant. Most of the specimens were collected south of Kampong Tekek, where a bar across the mouth of a stream impounds its outflow into a stagnant pool which has its only outlet by way of seepage through the sand of the beach front (see Bullock, this *Bulletin*, p. 4). This area is relatively open and sunlit; there was an extensive mat of freshwater algae.

This is the commonest rice field frog in most parts of Malaya. On Tioman there is no wet rice cultivation and no indication that there ever has been such; *Rana erythraea* lives in the nearest approach to a rice field habitat which is available to it on Tioman.

Rana hosii Boulenger. Hose's Cataract Frog.

The 1962 expedition took none of this species; I collected four adult females near the site of Camp II in May, 1958:

No. 3018 — 89.0 mm. snout-vent length (swollen oviducts, but no large ova).

No. 3019 — 88.9 mm. snout-vent length (1.9 mm., unpigmented ova).

No. 3042 — 90.2 mm. snout-vent length (1.8 mm., unpigmented ova).

No. 3043 — 93.0 mm. snout-vent length (swollen oviducts, but no large ova).

When compared with available large females from Selangor and central Pahang, the Tioman specimens showed no distinctive differences.

It is assumed that the two ovigerous females from Tioman were almost ready to breed and the other two with swollen oviducts had just laid their eggs. *Rana hosii* from Pahang in my collection have loose abdominal eggs which measure approximately 2 mm. in diameter.

Rana hosii is an inhabitant of the vicinity of fast-flowing upland forest streams. It looks superficially like a giant form of *Rana chalconota* and the two species are often found in association, but *hosii* is most commonly found at night sitting on rocks very near the faster water, while *chalconota* is usually perched on nearby vegetation. The more completely webbed feet of *hosii* are probably an adaptation for fast water and its tadpole (apparently unknown) may well be equipped with a sucker; the unpigmented eggs indicate some special site of deposit. (The rather ordinary-looking larvae of *chalconota* hatch from the usual sort of eggs with black and white hemispheres, laid in relatively quiet pockets of clear water along streams).

Rana chalconota (Schlegel). Malayan Bush Peeper.

Forty-two specimens are available, most taken during the recent visit in 1962. The collection includes 19 females (11 with large eggs) and 23 males. Comparison with specimens from Singapore, Johore, South Pahang, Selangor and other parts of Malaya reveals no distinctive differences on the part of the Tioman individuals.

This is a frog of forest streams, frequenting mainly the plant growth on stream margins. On Tioman it is found mainly on the higher ground where the forest is less disturbed, although it follows the stream courses down to the coastal plain and a number of specimens in this collection were taken at low elevations. In some respects it is the upland ecological counterpart of *Rana erythraea*, preferring more shaded surroundings and moving, clear water, although it appears to do well in swampy situations where these exist in the forest.

Rhacophorus leucomystax (Boie, in Gravenhorst, 1829)[21]. Common Tree Frog.

A single mature female (No. 5093) from Kampong Tekek; snout-vent length 68.6 mm., with 2 mm. diameter eggs. When compared with 3 comparable-sized female specimens from Rompin, Pahang (50–60 airline miles from Tioman) and 3 from Singapore, no striking differences were noted. The skin over the fronto-parietal and part of the squamosal area is fused to the skull in all 7 specimens; it is not fused to the nasal bones in any of them. The Tioman specimen agrees with Rompin females in having a heavier skin fold over the tympanum than do the Singapore females. It shows the common dorsal pattern of four primary and two subsidiary longitudinal stripes; in this it matches the Singapore animals, but differs from the three available large females from Rompin, which are plain with a few small dark blotches dorsally. However, several smaller Rompin specimens show this striped pattern, which appears to be more uncommon in that particular population than in most *leucomystax* in other parts of the Peninsula. No particular taxonomic importance is assigned to this matter of dorsal pattern, spotted frogs having been taken in amplexus with striped frogs and, on one occasion, a large number of progeny having been reared from this union. It is believed that the character is genetically controlled, but not an indicator of genetic isolation; Church (in litt.) discusses the inheritance of pattern in this species.

Rhacophorus leucomystax is very much a follower of man in South-east Asia; in the present case the specimen was taken in a rural village environment. It is one of the commonest frogs of the Malayan area, and is certainly the commonest around human habitations. It is almost invariably the first frog brought in by local children when a collecting party moves into an area and announces that the scientists are interested in seeing any animals which they can catch. Yet only this one specimen was taken (by a University collector) on Tioman in a collecting campaign which included well over 100 man-hours of work with lights at night and which should on the mainland have produced a large number of *Rhacophorus leucomystax*. In 1958 the writer spent considerable time night-lighting in and around Kampong Tekek, and never saw a single specimen of this species; neither were any heard croaking during his visit (the calls of these frogs were usually ubiquitous elsewhere).

21. I follow Inger (1954) in attributing the name *leucomystax* to Boie, whose manuscript on the herpetology of Java was never published, but whose specimens, with his manuscript names, were sent to other museums and reported on by other workers. Gravenhorst (1829) makes it clear that *leucomystax* was one of Boie's new species.

Is this by chance an example of an introduced individual (see account of *Bufo parvus*) or are there factors on Tioman which induce rarity in this otherwise abundant species? It must be admitted that no frog in Malaya seems more likely to be transported by man than *Rhacophorus leucomystax,* which lives most abundantly immediately around human habitations, often dwelling within houses and breeding in domestic water containers and impoundments. It resists dessication well when tightly folded in its resting posture, and would be quite likely to insert itself into bundles of materials which were made up for transport. It is possible that this frog is rather frequently brought to Tioman from the mainland and that, despite frequent introductions, it has never been able to establish itself successfully. The principal areas of human habitation in which introduced frogs would have to "start" are on sandy beach areas where there is little standing water except the brackish swamps behind the beach front. Although suitable breeding sites and larval habitats exist, they may be beyond the reach of frogs put ashore at the village sites.

Philautus petersi (Boulenger). Mountain Tree Frog.

Ixalus petersi Boulenger, 1900, Proc. Zool. Soc. London, 1900 : 185, pl. 17, fig. 3.

Philautus petersi M. A. Smith, 1925, Journ. Sarawak Mus., 3 : 10; idem., 1930, Bull. Raffles Mus., 3 : 116.

Ixalus larutensis Boulenger, 1900, Ann. Mag. Nat. Hist., (7) 6 : 187; idem., 1903, Fascic. Malay., Zool. 1 : 139, pl. 5, fig. 3 & 4; idem., 1912, Vert. Fauna Malay Pen., Rept. & Batr. : 253.

Ixalus castanomerus Boulenger, 1905, Journ. Fed. Malay States Mus. 1 : 39, pl. 4, fig. 1; idem., 1912, Vert. Fauna Malay Pen., Rept. & Batr. : 254.

A single adult male (No. 5314) taken near Camp V, 2,500 feet, Ulu Lalang.

This identification is made with some diffidence; as Smith (1930) and Inger (1954) point out, the *Philautus* group badly needs revision and it is extremely difficult to be confident of identifications made by reference to many of the published descriptions. I have not had access to any of the type specimens but, after study of Boulenger's descriptions and figures of *petersi, castanomerus* and *larutensis* and acceptance of Smith's (1930) lumping of all these into *petersi,* I find that my specimen agrees well with the enlarged scope of *petersi.* I also note that Inger (1954, p. 403) notes, after examination of the types of *petersi,* that they have the skin along the outer edge of the fifth metatarsal crenulated and that the snout of *petersi* usually bears a dermal projection. My specimen has the tarsal skin faintly but unmistakably crenulated; it also shows a small fold of skin across the snout between the nostrils which I would ordinarily have dismissed as a wrinkle acquired during preservation due to pressure of some sort on the nose in a crowded preserving jar.

The specimen measures 21.9 mm. in snout-vent length; it has well-formed, but not large, testes. The bilateral openings to the vocal sacs are clear. There are clearly-raised, non-pigmented, non-spinose nuptial pads on the medio-dorsal aspects of the bases of the first fingers.

This individual was found sitting on a palm leaf, (*Licuala* sp.) off the ground and was located by its distinctive call. Calls were frequently heard in the forest above 2,500 feet, but nowhere below this elevation.

DISCUSSION

The amphibian fauna of Pulau Tioman appears to be peculiarly unbalanced, with a number of conspicuous gaps in species representation as compared with the adjacent Malayan mainland. The complete absence of microhylids in our collections is noteworthy; so is the absence of any members of the widespread and hardy genus *Bufo* except for the solitary, enigmatic specimen of *Bufo parvus* collected. The whole group of rhacophorids, so populous and widespread over South-east Asia, is represented in our collections by a single specimen of *Rhacophorus leucomystax*, believed to be an introduced individual without meaning for the species.

I believe that the composition of the present fauna can be satisfactorily explained in its special context by the same Pleistocene history postulated in the accompanying paper on reptiles. By virtue of the permeable skin of the adults and, most particularly, by virtue of the strict requirements of the aquatic larvae of many species, the amphibian fauna of an island such as Tioman might be expected to show rather clearly the influence of physiography and climate, both present and past.

Of the 12 species of amphibians collected on Tioman, only four are bound closely to slow-moving or standing water (*many* of the "absentee species" mentioned above are so-bound). The remaining eight Tioman species are either adapted for life in or near fast-flowing upland streams or are more or less independent of any larger water bodies by virtue of some special adaptation. *Bufo parvus, Rhacophorus leucomystax, Rana erythraea,* and *Rana cancrivora cancrivora* all have larvae requiring quiet water habitats which are very limited on Tioman (and may have been even more limited in the past). I believe that the first three of these are introduced species, brought accidentally to the island by human agency (it seems possible that the *Bufo* and *Rhacophorus* are not successful immigrants). The fourth species, *Rana cancrivora cancrivora,* is the one lowland frog which I believe to have survived on the island from ancient times, finding suitable brackish habitat here and there along the coastline as the sea level went up and down.

The remaining eight species I believe to be all relicts, surviving on the island since it was isolated by rising Pleistocene seas. Four of these are probably independent of permanent surface streams and would appear to have been particularly well adapted to survive the postulated times of crisis when a raised sea level forced terrestrial life up to the higher portions of the island where the terrain was steep, rocky, and excessively well-drained. *Pelophryne signata* probably breeds in tiny, hidden pockets of entrapped rain water among the leaves of the forest floor. The two specimens of *Ansonia tiomanicus* were found in a cave, which was also a major drainage channel and probably provided a suitable underground habitat for the (presumably) sucker-bearing larvae. The *Discodeles/Platymantis* group of frogs are thought to produce terrestrial eggs and to have no free larval stage. *Philautus petersi* belongs to a group which largely occurs at higher altitudes, commonly in rocky mountain-top situations; it probably breeds in entrapped water in tree holes or leaf axils.

The last four species are all characteristic of upland stream courses, where the water usually flows clear over rocky beds (closely comparable with the Sungei Ayer Besar on Tioman). *Rana chalconota* can also be found in wooded, swampy areas, but it is most dependably found in the brush fringe of small, moderately fast brooks. Its larvae live in the quieter pools where there are accumulated leaves but little or no silt. I have never found *Rana hosii* away from moving water and rocks; its larva is apparently not definitely known, but is suspected to be a sucker-bearing tadpole inhabiting fast water. *Megophrys monticola nasuta* is a

true forest frog and wanders far from water; it returns to streams to breed, and its larvae live best in very shallow trickles of clear water. *Rana blythii* is the common dominant frog of Malayan upland forest streams; its larva and method of reproduction are unknown. It has been suggested to me by Malayan aborigines that the adult constructs a small pool for reproductive purposes. The adult frogs are important in the aboriginal diet and the people claim that they make a conscious effort at conservation by taking care not to step in or otherwise disturb the "nurseries" from which more eatable frogs may someday come. The fact that *blythii* eggs are unpigmented is not inconsistent with a habit of placing the eggs in some special, more or less concealed, place.

It seems to me that the amphibian fauna of Tioman fits very neatly into the historical picture which was postulated in the discussion of the reptile fauna. By their ecology the nine species considered here as relicts seem particularly well-fitted to have survived times of stress which would have eliminated many other species. I venture to predict that any further species discovered on Tioman will either show comparable special features of their life cycle or their appearance will correlate suspiciously with some particular new human activity.

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7. The Food of the Amphibians and Reptiles

By J. A. Bullock

INTRODUCTION

The amphibians and reptiles collected on the expedition offered an opportunity to examine the diet of a restricted fauna in relation to its ecology. Knowledge of the food of the Malayan amphibians is restricted to a single study of the food of *Bufo melanostictus* Schneider (Berry and Bullock, 1962) while in the reptiles only the snakes have received attention (Lim, 1956). As has been noted by Hendrickson (this *Bulletin*, p. 72) the amphibians were represented on Tioman by numerous individuals, but relatively few species, and these circumstances provide good conditions for determining the extent of feeding segregation of the different species. The reptiles had a greater species representation but again were generally more abundant than on the mainland and for many species sufficient data were obtained to indicate the type of diet.

MATERIALS AND METHODS

The entire collection of amphibians and reptiles resulting from the expedition was used for this study although a number of specimens contained no food, e.g., all the snakes, and these, except in special cases, are not included in the account. The amphibia were all collected by hand and were killed by immersion in 70 per cent alcohol, usually within an hour of capture and always within three hours. The specimens were sorted and labelled on the same day as they were killed and the wall of the abdomen cut with fine scissors to ensure penetration of the viscera and preservation of the gut and its contents.

The reptiles were treated in much the same way as the amphibia except that these were almost entirely collected by shooting with "dust" shot so that death may be considered to have been instantaneous. Preservation of specimens was often rather delayed because they were collected while out on a day's collecting when preservative could not be carried.

For examination, the abdomen was opened by a longitudinal cut in the abdominal wall and a lateral cut along the lower edge of the pectoral girdle. The stomach was then removed by cuts across the oesophagus and the small intestine and placed in a tube of 70 per cent alcohol together with a copy of the collection number of the specimen. Analysis of the contents was made by opening the stomach with fine scissors either in a petri dish or, in the case of small stomachs, e.g. *Pelophryne signata*, in a glass block under a dissecting microscope. The contents were then classified as far as possible, no identification being taken beyond family since this was the furthest that most specimens could be taken with any degree of accuracy.

TABLE 1

The food of five species of amphibia, expressed as a percentage of stomachs containing each item.

Species	*blythii*	*erythraea*	*chalconota*	*cancrivora*	*P. signata*
No. of stomachs containing food	46	31	21	7	6
Annelida	9	—	—	—	—
Mollusca					
Slugs	4	—	5	—	—
Snail	17	—	14	—	—
Crustacea					
Amphipoda	—	12	—	43	—
Isopoda	—	—	10	14	—
Decapoda	15	— (3?)	—	29	—
Arachnida					
Thelyphonida	2	—	—	—	—
Scorpionida	2	—	—	—	—
Phalangida	6	—	—	—	—
Aranea	33	36	34	57	17
Acari	—	—	—	—	67
Myriapoda					
Chilopoda	9	—	—	—	—
Diplopoda	17	—	5	—	—
Insecta					
Machilidae	2	—	—	—	—
Collembola					
Arthropleona	—	6	—	—	—
Symphyleona	—	6?	—	—	33
Ephemeroptera	2	—	—	—	—
Odonata	2	—	5	—	—
Blattaria	13	6	—	14	17
Orthoptera					
Gryllidae	11	—	10	—	—
Tettigoniidae	—	3	19	—	—
Tridactylidae	—	3	—	—	—
Acrididae	—	3	—	—	—
non-determined	24*	—	14	14	—
Isoptera	4	—	5	—	—
Thysanoptera	—	—	5	—	17
Homoptera					
Cicadidae nymph	4	—	—	—	—
Jassoidea	—	3	—	—	—
Fulgoroidea	—	—	5	—	—
non-determined	—	—	5	—	—
Heteroptera					
Hydrometridae	—	6	—	—	—
Gerridae	—	52	—	14	—
Veliidae	—	3	—	—	—
non-determined	6	3	—	—	—
Trichoptera	2	—	—	—	—
Lepidoptera	4	—	5	—	—
larvae	17	3	10	—	—
Coleoptera					
Scarabaeidae	4	—	5	—	—
Carabidae	4	—	—	—	—
Melolonthidae	11	—	—	—	—
Curculionidae	4	—	—	—	—
Elateridae	6	—	—	—	50
Cerambycidae	6	—	5	—	—
Lycidae	2	—	—	—	—
non-determined	36	—	14	—	17
Hymenoptera					
Formicidae	33	18	29	—	100
non-determined	—	12	—	—	—
Diptera					
Muscoidea	4	—	—	14	—
Tipuloidea	2	—	—	14	—
non-determined	—	18	—	—	17
pupae	—	—	—	14	—

*Apparently mainly Stenopelmatidae with a few Gryllidae.

TABLE 2

The food of the same five species as in Table 1, expressed as the number of items per 10 stomachs, with an estimate of their importance. (V= Very important in diet (also indicated by bold-face setting); I=Important in diet; S=Slight importance in diet; U=Unimportant.)

Species	*blythii*	*erythraea*	*chalconota*	*cancrivora*	*P. signata*
No. of stomachs	46	31	21	7	6
Annelida	0.9 S	—	—	—	—
Mollusca					
Slug	0.9 S	—	0.5 S	—	—
Snail	2.0 I	—	2.0 I	—	—
Crustacea					
Amphipoda	—	2.3 I	—	**22.9** V	—
Isopoda	—	—	0.7 S	5.7 I	—
Decapoda	1.8 I	0.3? S	—	**4.3** V	—
Arachnida					
Thelyphonida	0.2 S	—	—	—	—
Scorpionida	0.2 S	—	—	—	—
Phalangida	0.7 S	—	—	—	—
Aranea	3.9 S	4.7 I	4.0 S	10.0 I	1.7 S
Acari	—	—	—	—	67.0 V
Myriapoda ..					
Chilopoda	0.9 S	—	—	—	—
Diplopoda	2.4 I	—	0.3 U	—	—
Insecta					
Machilidae	0.2 U	—	—	—	—
Collembola					
Arthropleona ..	—	0.7 U	—	—	—
Symphypleona ..	—	2.7 U	—	—	6.7 S
Ephemeroptera ..	0.2 U	—	—	—	—
Odonata	0.2 U	—	0.3 U	—	—
Blattaria	2.0 I	1.7 I	—	1.4 S	5.0 I
Orthoptera					
Gryllidae	**1.6** V	—	**1.0** V	—	—
Tettigoniidae ..	—	0.3 I–S	**2.3** V	—	—
Others	**2.6** V	0.6	**1.0** V	1.4 S	—
Isoptera	7.8 S	—	4.5 S	—	—
Thysanoptera	—	—	0.3 U	—	1.7 U
Homoptera					
Cicadidae n.	0.4 S	—	—	—	—
Jassoidea	—	0.3 U	—	—	—
Cercopoidea	—	—	0.7 U	—	—
non-determined ..	—	—	0.3 U	—	—
Heteroptera					
Hydrometridae ..	—	0.7 U	—	—	—
Gerridae	—	**23.3** V	—	1.4 U	—
Veliidae	—	0.3 U	—	—	—
non-determined ..	0.7 U	1.7 S	—	—	—
Trichoptera	0.4 U	—	0.3 U	—	—
Lepidoptera	0.4 U	—	0.3 U	—	—
Larvae	2.0 I–S	0.3 S	0.7 S	—	—
Coleoptera	**9.1** V	—	2.5 I	—	10.0 I
Hymenoptera					
Formicidae	11.3 S	2.0 S	7.5 I–S	—	**80.0** V
non-determined ..	—	1.3 U	—	—	—
Diptera					
Muscoidea	0.4 U	—	—	1.4 U	—
Tipuloidea	0.2 U	—	—	2.8 S–U	—
non-determined ..	—	5.3 S	—	—	6.7 U
pupae	—	—	—	* U	—
Mean no. of items per individual	5.34	4.85	2.89	5.13	17.88

*A confused mass of pupae in one stomach only.

Records were kept of the number of specimens of each group found in the individual stomachs and, where specimens were more or less complete, the length was also noted. Since the main purpose of this study was to answer two questions: "What food do the various species take?" and "What differences exist between the diets of different species?" it was not considered necessary to measure the volume of the items as has been advocated by Inger and Marx (1961). The answer to the first question is obtained from the straight identification of the stomach contents and that of the second by determining the frequency of occurrence in stomachs (Table 1) and the number of items per stomach (Table 2). That this gives no indication of the actual food value to the animal is true, but it must be doubted whether the use of volume gives any but the very broadest indication of this, since two assumptions are made which are certainly doubtful:

(i) that the food value of prey of the same size is approximately equal.

(ii) that different types of prey undergo digestion at the same rate. (Inger and Marx (loc. cit.) only accepted items which were more or less entire, i.e., undigested).

It is considered that adequate identification coupled with a simple record of length gives satisfactory data. Thus, a scarabaeid beetle is always roughly the same shape, an ant is always ant-like, etc. On this basis, various items have been assessed as very important (V), important (I), of slight importance (S), and unimportant (U), having due regard to the number of items and their relative size (Table 2).

THE FOOD OF THE AMPHIBIA

Of the eleven species of amphibia collected, only three yielded sufficient data for conclusions to be drawn as to their feeding habits, while two others yielded sufficient information to give a reasonable indication of diet. These are summarised in Tables 1 and 2, which show respectively the percentage of stomachs in which each item was recorded (Table 1), and the mean number of items per 10 stomachs and the rank accorded to the items on a basis of relative size (Table 2).

Rana blythii

The dominant group taken by this frog was Coleoptera which were found in some 67 per cent of all the stomachs examined. Breakdown of the Coleoptera to family level reveals a wide range with no definable feeding preference. The next most frequent order was the Orthoptera in which gryllids and stenopelmatids were the main families. The next in terms of the number of stomachs from which they were recorded were the ants and the spiders. The ants were small and of slight dietary value as may be seen by reference to their ranking and this is reinforced by the fact that 28 of the 52 ants recorded were found in one stomach. The spiders were very variable; some large mygalomorphs obviously made a definite contribution to the diet, but others (and these were in the majority) were small specimens of little significance. Of the remainder, blattids, snails, diplopods, lepidopteran larvae and crabs formed a major item in the diet of some specimens whilst other items were too small and/or too infrequent to be of significance.

The diet is thus dominated by predominantly litter-dwelling forms[22] with the exception of some of the Coleoptera. Of these latter, however, many of the forms found spend at least part of their life on and below the soil surface, e.g., melolonthids often oviposit on the soil and the immature stages are subterranean. The few forms which are normally found in flight may be accounted for by the accidents

22. For a discussion of insects occurring in different habitats see Bullock, this *Bulletin* p. 104.

which flying insects encounter, to descents to objects within "frog-range" of the litter layer or to actual occurrence on the layer either at emergence or at oviposition. The considerable diversity of items shows little selectivity and it is apparent that the majority of litter-dwelling forms are readily taken (with the possible exception of ants).

Rana erythraea

The outstanding item in the diet by number of stomachs, numbers taken, and size was the gerrids, whilst spiders of a size comparable to that of the gerrids figured frequently. No other items were found sufficiently often to warrant consideration as major items in the diet although the character of several are worthy of notice since they are forms which are closely associated with water, i.e. hydrometrids, veliids, amphipods and adult chironomids, together with one of the Orthoptera, a tridactylid, which was only found near water. The spiders were mainly tetragnathines which were particularly abundant over the pool where all the specimens of this frog were collected.

The frogs were mainly immatures and adult males (which are appreciably smaller than the adult females) and were collected from a floating algal mat and from the edges of a pond. The character of the diet reflects this habitat; the principal prey comprised animals occurring on the surface of the water while blattids, etc., were possibly captured during short excursions on to the shore. It should be noted, however, that the capture of terrestrial forms might be due either to their incursion on to the algal mat, or to their falling into the pond. The evidence indicates that *R. erythraea* does not feed on the truly aquatic animals, of which there was an abundance in the pond, nor does it stray far from water.

Rana chalconota

In this species the most important item of diet, both by number of stomachs and bulk, was the Orthoptera and of this order the tettigonids were the most frequent. Ants and spiders also contributed to a slight extent but this cannot be regarded as very significant in terms of bulk, whilst the Coleoptera were less important than in *R. blythii*. Other categories were poorly represented and, in fact, few of the animals appeared to have fed well, the mean number of items per stomach being about two-thirds that of the other ranids with little or no indication of a proportional increase in the size of the prey (cf. Table 2, last line).

The diet suggests that *R. chalconota*, which was collected from the same habitat as *R. blythii*, differs from the latter in that different emphasis is placed on the food available. Thus among the Orthoptera, tettigonids replace gryllids and stenopelmatids; blattids do not occur; the myriapods are represented by a single specimen; and the significance of the Coleoptera, especially the heavier forms, has decreased. This, therefore, suggests the partial elimination of the litter-dwelling forms and their replacement by leaf-dwelling types, in accordance with the frog's habit of perching on branches above the ground.

Rana cancrivora

The diet of this species, insofar as 7 stomachs can give an indication, was dominated by non-insectan elements with amphipods and crabs of greatest importance. Both these forms are littoral and this impression of the diet is enhanced by the presence of isopods, a gerrid and both adult and pupal limoniids. The diet therefore reflects a habitat confined to the proximity of water, but not necessarily carrying an insect fauna, the majority of forms being characteristic of the more or less brackish meanders (cf. Bullock, p. 113), near which all specimens of the frog were collected.

Pelophryne signata

The diet of this small bufonid consisted of small ants and mites together with a number of other forms, including a small elaterid beetle. Over 90 per cent of the items recorded were less than 2.5 mm. in length, and only one specimen, an ant, exceeded 4 mm. The small size of the prey is in part related to the small size of the toad, but even so the size of prey is disproportionately small when compared with the Ranidae; this is reflected in the greater number of items recovered from each stomach (Table 2, last line). The feeding pattern therefore indicates a small animal feeding on numerous very small arthropods and not relying, as do the ranids, on fewer comparatively large animals. *P. signata* lives in primary forest as do *R. blythii* and *R. chalconota* but it is far less confined to the proximity of water. Even if this were not the case, the very small forms constituting its diet would effectively prevent competition with the ranids. (*P. signata* is incidentally so small that it could well form an item of food for *blythii*.) Although the toad was occasionally taken on foliage, the items recorded are more typical of the litter layer.

Other species examined

Bufo parvus.—The single specimen had taken a mixed diet of ants (8), isopods (9), a gryllid and a phalangid.

Ansonia tiomanica.—The two specimens had taken between them ants (17), arthropleonan collembola (7), a beetle, a heteropteran bug, a dipterous larva, a parasitic wasp, a chilopod, a spider and a mite, and the vast majority of these items were taken from a single specimen found outside a cave; the second specimen, which came from within the cave, only accounted for one ant and the wasp.

Rana (*Discodeles*/*Platymantis*) sp.—The only identifiable remains were of a lone ant.

Megophrys monticola nasuta.—All four specimens had fed poorly and only two ants, an isopod, two spiders (one large), and a large, well-digested orthopteroid could be discerned.

Racophorus leucomystax.—The stomach of the single specimen contained only a lygaeid bug.

SUMMARY OF THE FEEDING HABITS OF THE AMPHIBIA

The diet of *R. blythii* is dominated by the litter-dwelling or litter-visiting forms and that of *chalconota* by the types living on herbage above the litter. *Pelophryne signata* is not competing with these two species since its small size confines it to prey of lesser size, and it is less restricted in habitat than the two ranids which are confined to the riparian fringe. Moreover it appears to accentuate this division by concentrating on prey which is proportionately smaller than that of the other two. *R. erythraea*, which on Tioman was only recorded in one place, is apparently confined in its feeding to those animals which find their way onto the floating algal mat on which it was normally found, although it may occasionally wander into the littoral zone. In this wandering, it may overlap with *R. cancrivora* which was also confined to the coastal area but the nature of the latter's diet suggests a preference for crustacea. It is apparent that feeding is confined by:

(*a*) the preferred feeding site of the amphibian; and

(*b*) the size range of prey which is acceptable.

Apart from these two factors, there is little evidence of selectivity except that ants, which were a very prominent constituent of the litter fauna, might have been expected to occur in greater numbers in the diet of *blythii*. This, however, may not

have been the result of a preference in diet but in feeding site, e.g., avoidance of ant runs. Tyler (1958) has noted an avoidance of ants in *Rana esculenta* but the percentage of *blythii* which had taken ants, albeit only in small numbers, renders such an explanation doubtful in this case.

THE FOOD OF THE REPTILIA

The collection of reptiles was more limited in terms of length of series than was the amphibian collection and consequently it is more difficult to delimit the diets. A single table of stomach contents (Table 3) has therefore been drawn up to indicate the presence or absence of items in the diet. An indication of the apparent significance in the diet is also given as well, based on the number of stomachs in which the item was recorded.

Goniocephalus grandis

Eight stomachs of this large lizard contained food and the identifiable items suggest a catholic diet. Six specimens contained caterpillars measuring between 10 and 25 mm., three had been feeding on large beetles including both cerambycids and chrysomeloids, and large orthopteroids were recorded in three specimens. Other large items included two thelyphonids about 30 mm. long which were found in one stomach, and large ants (presumably *Camponotus gigas*) which were found in two. Various smaller arthropods, including small ants, beetles, flies and spiders, were also recorded together with a single ascalaphid larva.

The general picture of the diet suggests a mainly arboreal form although the presence of thelyphonids and a large cockroach may indicate that the lizard, at least occasionally, descends to the ground to feed.

Goniocephalus chamaeleontinus

Of the six specimens examined, only three contained any identifiable food remains, although one of the "empty" stomachs is of interest in that it was full of soil. All recognisable items of foods were large, the largest being a scolopendrid centipede measuring over 40 mm. Other items were two large caterpillars, a large orthopteroid, a polydesmoid millipede and an earthworm. Although this is insufficient evidence from which to draw general conclusions, it can be asserted that *G. chamaeleontinus* hunts on the ground for part of its food, as is indicated by the presence of soil and of an earthworm, whilst the large myriapods are more likely to have been found there than in an arboreal habitat.

Goniocephalus armatus

Only three specimens were examined, including one collected by Hendrickson on his visit to Tioman in 1958. One of these had taken two earthworms and a scarabaeid beetle (elytra 9 mm.) and in a second the only identifiable remains were of a small ant. The third specimen had an empty stomach but examination of the rectum revealed a mass of soil. This evidence again clearly suggests a terrestrial foraging habit.

Draco melanopogon

The outstanding item in the stomach of all eight specimens was ants of which approximately 300 were recognisable and included several species of which the majority were 4-5 mm. long. Other forms were relatively few although both larval and adult beetles, two millipedes, two isopods and six termites were found. It is obvious that these were of little importance in the diet and that *D. melanopogon* has a highly specialised diet to which its habit of hunting on the trunks of trees is admirably adapted.

TABLE 3

Occurrence of items in the stomachs of lizards. (+ = Present in one stomach only; ++ = Present in more than one but not more than 50% of stomachs*; +++ = Present in more than 50% but less than 90% of stomachs†; ++++ = Present in more than 90% of stomachs.)

	Goniocephalus grandis	*G. chamaeleontinus*	*G. armatus*	*Draco melanopogon*	*D. volans*	*Calotes*	*Lygosoma*	*Cnemaspis kendalli*	*Cnemaspis sp.*	*Aphanioitis*	*Dasia*	*Mabuya*
No. of stomachs ..	8	3	2	8	6	3	3	3	4	8	4	4
Annelida ..		+	+					+				
Mollusca												
Snails ..	+											
Crustacea												
Isopoda ..												++
Arachnida												
Thelyphonida ..	+											
Phalangida ..							+					
Aranea ..	+											++
Myriapoda												
Chilopoda ..		+										
Diplopoda ..		+		++			+	+		++		
Insecta												
Collembola ..							+					
Orthoptera												
Gryllidae ..												+
Tetrigidae ..												+
non-determined	++			+					++			
Blattaria ..	+											
Isoptera ..				+	++					+		
Thysanoptera ..				+								
Heteroptera ..	+											
Neuroptera larva	+											
Lepidoptera larvae	++++			+		+	+		+	+++	+	
Lepidoptera pupa										+		
Coleoptera												
Chrysomeloidea	+											
Cerambycidae	+											
others ..	++					+	++	+	+	++	+++	+
larvae ..	+		+	++								
Hymenoptera												
Formicidae ..	++		+	++++	++++	+	++	+	+	++	+	+
Apidae ..	+					++					++	
non-determined							++					
Diptera												
Muscoidea ..	++					+					+	
Reptilia												
Scincid scutes ..											+++	
Soil remains‡ ..		++	+					++				

*Not applied to *G. armatus*; where only three stomachs were examined the item was recorded from more than one.

†Not applied where less than four stomachs were examined.

‡Includes stomachs otherwise empty.

Draco volans

As in the previous species, the diet of this lizard is dominated by ants. The only other constituent in the six specimens examined was a few alate termites, and the diet clearly indicates a similar feeding preference to that of *D. melanopogon.*

Calotes cristatellus

The data obtained from the three specimens examined and found to contain food is too slight for any conclusions to be drawn. Two specimens had taken large aculeate hymenopterans, together with an ant in one and the remains of a large fly in the other. The third specimen contained a large beetle (probably Scarabaeidae) and a caterpillar about 14 mm. long.

Aphaniotis fusca

The diet of this species is clearly dominated by caterpillars which were recorded from five of the eight stomachs examined and which, when sufficiently intact for measurement, ranged between 9 mm. and 15 mm. in length. Other forms recorded included a number of beetles, three polydesmoid millipedes, two cockroaches and seven termites. Ants were few, a total of five being recorded, which contrasts strongly with *Draco* which lives in the same habitat and feeds almost exclusively on these forms. The evidence indicates an arboreal feeding habit with the species clearly not competing for food with *Draco*, a species of similar size as well as habitat.

Mabuya multifasciata

Four of the stomachs contained food, but no item occurred in more than two. Three specimens of a large cockroach *circa* 24 mm. long were recorded in one stomach while isopods and spiders occurred in two. Other forms were represented by single specimens only and these included a tetrigid, a large ant, a grylloid and a small bug. The inference is that *M. multifasciata* feeds on litter- and rock-dwelling forms, which accords with its known habitat preference.

Lygosoma scotophilum

Three stomachs contained food and in one of these the only item was a small rock-dwelling beetle, probably a lichen feeder, of which at least ten specimens had been taken. The other two had taken a varied diet including caterpillars (*circa* 10 mm. long), ants, a phalangid, a polydesmoid millipede and two collembolans. All these forms are likely to be found on boulders, or in crevices amongst them, and the diet suggests a fairly catholic acceptance of arthropods within the scincid's chosen habitat.

Dasia olivacea

Of the four specimens examined, three contained scincid scutes. Although in one specimen only a tail could be discerned, in a second specimen remains of the body were clearly visible including a foot and parts of the trunk. Unfortunately, accurate identification is not possible but it seems very probable that these records indicate cannibalism especially since this species did not overlap with either of the other two scincids recorded on the island (Hendrickson, this *Bulletin,* p. 66).

The rest of the diet offers little evidence on the feeding habits. Small bees (probably *Trigona* sp.) were recorded in two stomachs, and beetles in three but these were too far digested to permit identification even to family. The only other items were a caterpillar, an ant and a large muscoid fly. The presence of so many bees cannot be taken as conclusive proof of arboreal feeding since some bees frequently nest on or near the ground and the lizard may have been feeding at the entrance to such a nest.

Cnemaspis kendalli

Six stomachs of this gekkonid were examined and although only three contained food, two of the others are of interest since they contained large quantities of soil. A further specimen had taken two ants and again the stomach was full of soil. Of the other two, one only contained pieces of an earthworm and the other a small scarabaeid and pieces of a small polydesmoid millipede. This diet therefore indicates a terrestrial-foraging form which concentrates more on the soil layer than on the litter-dwelling forms.

Cnemaspis sp.

The diet of this form, as indicated by the four stomachs which contained food, is distinctly different from that of *C. kendalli*. In no case was soil recorded, nor was there evidence of soil-dwelling forms. One specimen had taken two caterpillars, one of which was a geometrid measuring *circa* 20 mm. in length, while well-digested orthopteroid remains were recovered from two stomachs. The only other items found were a beetle and an alate ant. The evidence, whilst indicating reasonable catholicity, is too slight for conclusions about the feeding site to be drawn although the geometrid suggests at least partly arboreal feeding.

Hemidactylus frenatus

The single specimen examined only contained a small muscoid fly.

Gehyra mutilata

Again only a single specimen contained food and the only identifiable item was an isopod although two much-digested small insects were also present together with a large leg, probably that of a cockroach.

Varanus nebulosus

The only specimen containing food was a juvenile which had taken one small cricket. However the form was frequent about Kg. Tekek and specimens were observed foraging amongst refuse on several occasions.

Ophidia

None of the specimens collected contained identifiable food remains. Hendrickson (p. 67) recorded a python (*Python reticulatus*) in a sea cave on the east side of the island which had recently eaten a mouse-deer.

SUMMARY OF THE FEEDING HABITS OF THE REPTILIA

The general impression of the diets of the forms examined is of reasonable catholicity of taste with the exception of the two species of *Draco* which concentrated on ants to the near exclusion of other forms. In all other cases the diet appears to be correlated with the preferred habitat and feeding site of the species. Thus

Goniocephalus grandis and *Aphaniotis fusca* have mainly arboreal diets although in at least the former there is evidence to suggest occasional descents to the ground. The other two species of *Goniocephalus, chamaeleontinus* and *armatus*, are clearly terrestrial foragers for at least part of their food and both appear to forage in the soil as well as in the litter layer. *Cnemaspis kendalli* parallels these two forms whilst *Cnemaspis* sp. is probably partly arboreal. Both *Mabuya multifasciata* and *Lygosoma scotophilum* are terrestrial feeders but whilst *multifasciata* feeds generally in this zone, *scotophilum* is probably more or less confined to the vicinity of boulders. Of the other forms, no indication of feeding niche can be obtained although in both *Calotes cristatellus* and *Dasia olivacea* there are indications of a catholic diet. None of these results contradict Hendrickson's observations on the habits of the animals.

TABLE 4

Summary of the habitats, feeding sites and type of food taken by the commoner species of Amphibians and Reptiles* collected on P. Tioman

Species	*Habitat*	*Feeding site*	*Type of food*
Rana blythii ...	Primary forest	Terrestrial	Catholic
Rana chalconota	Primary forest	Shrub	Catholic
Rana erythraea	Coastal plain	Freshwater	Mainly water-surface forms
Rana cancrivora	Coastal plain	Edges of freshwater and brackish pools	Littoral, mainly Crustacea
Pelophryne signata	Primary forest	Litter and herb layers	Very small forms
Draco volans ...	Plantations	Tree trunks	Mainly ants
Draco melanopogon	Primary forest	Tree trunks	Mainly ants
Goniocephalus grandis	Primary forest	Arboreal (mainly)	Catholic
G. chamaeleontinus	Primary forest	Terrestrial (at least partly)	Soil and litter forms
G. armatus ...	Primary forest	Terrestrial	Soil and litter forms
Aphaniotis fusca	Primary forest	Arboreal	Catholic
Mabuya multifasciata	Primary forest	Terrestrial	Litter forms
Lygosoma scotophilum	Primary forest	Boulders	Mainly rock-surface forms
Cnemaspis kendalli	Primary forest	Terrestrial (boulders)	Soil and litter forms
Cnemaspis sp.	Primary forest	Arboreal (at least partly)	Catholic
Dasia olivacea	Coastal	Partly arboreal	?Catholic
Calotes cristatellus	Mainly coastal	Belukar and riparian fringe	?Catholic
Varanus nebulosus	Coastal and forest	Mainly terrestrial (but capable of tree climbing)	?Catholic (Scavenging)

*I have utilised data in Hendrickson's account of the reptiles in preparing part of this table.

INTERSPECIFIC COMPETITION

Amongst the amphibians from which a definite indication of feeding habits was obtained, the data show more or less complete feeding segregation depending on habitat, feeding site, and size of the items taken. In the lizards, feeding segregation is less clear cut although habitat, feeding site and, in the case of *Draco*, food preferences play their part. In the two species of *Draco*, the food taken is the same, but these two forms are separated by their habitat preference, *D. melanopogon* occurring in primary forest and *D. volans* being confined to the coastal plantation area. *Goniocephalus grandis* and *Aphaniotis fusca* occupy the same habitat, are both mainly arboreal and both take the same type of food with caterpillars the most frequent item. In this case it may well be that there is sufficient food for both and that other requirements keep the two species from competing. There is some indication that the adult *grandis* subsists to a great extent on items too large for the considerably smaller *fusca* to take but this could hardly apply to the juveniles. Between *G. chamaeleontinus* and *G. armatus* there is again no evidence of segregation and these two and *Cnemaspis kendalli* appear to be living in competition in so far as our knowledge of their requirements goes. Where conclusions can be drawn as to diet in the other forms, it is apparent that habitat and feeding site supply an adequate segregation.

SUMMARY

The food of the amphibians and reptiles on Pulau Tioman, as indicated by an examination of the stomach contents of the specimens collected in 1962, is discussed and the evidence is used in an attempt to show ecological segregation. Where differences can be discerned, these are attributable to broad habitat requirements and to preferred feeding sites. Only in *Pelophryne signata* and the two species of *Draco* could definite food preferences be distinguished.

ACKNOWLEDGEMENTS

I am grateful to the various members of the expedition who assisted in the collection of specimens and to Professor J. R. Hendrickson for identifying the amphibians and reptiles, and the reptilian remains in the stomachs of *Dasia olivacea*. I am further indebted to Professor Hendrickson for permitting me to draw on data in his accounts of the reptiles and amphibians.

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8. Fishes of the stream drainages

By ERIC R. ALFRED

INTRODUCTION

UP TO NOW the only reported collections of fishes from Tioman are those listed by Tweedie (1936 & 1940) who included four species from fresh-water localities on the Island. These had been collected by the Fisheries vessel *Tongkol* in June 1926 and by the late Norman Smedley, formerly of the National Museum, in May 1927. Subsequent reports, viz., Fowler (1938), Hora and Gupta (1941), and Tweedie (1952 & 1961), have all referred to these same specimens.

During a field-trip to Tioman from 25th May to 7th June, 1958, the writer collected 196 specimens representing 20 species. This report deals largely with this collection and the material previously mentioned by Tweedie (loc. cit.). During the University of Malaya expedition in 1962, a few further specimens were taken from fresh-water and brackish localities and they were identified by Mrs. P. Y. Berry of the Zoology Department of the University. Five species were recorded and these were reported to me by Mr. J. A. Bullock and Lord Medway (in ms.) for inclusion in the present account.

The stream drainages have been described briefly by Bullock and Medway (this *Bulletin*, p. 4). During the 1958 trip, much time was spent collecting beyond the upper tidal limits of the Sungei Tekek, the Sungei Ayer Besar and the Sungei Bahru, mainly with a view to ascertaining the number of primary fresh-water species occurring on the Island. The apparent paucity of brackish water forms is therefore due mainly to inadequate collecting from brackish localities. New records for Tioman are indicated by an asterisk.

ANNOTATED LIST

Puntius lateristriga (Valenciennes) Figure 6.

Barbus lateristriga Valenciennes, In: Cuvier and Valenciennes, 1842, Hist. Nat. Poissons, 16:161 (Java).

Puntius lateristriga Tweedie, 1936, Bull. Raffles Mus., 12:20 (Sedagong River, Tioman Island, west coast Malay Peninsula); Weber and de Beaufort, 1916, Fishes Indo-Aust. Archipel., 3:179; Tweedie, 1961, Bull. Raffles Mus., 26:178 (Tioman Island).

Barbus lateristriga Fowler, 1938, Fish. Bull., 1:252 (Sedagong River, Tioman Island, west coast Malay Peninsula).

Previously known from 7 specimens taken by Smedley from the Sungei Sedagong (= Sungei Ayer Besar) at an elevation of 1,000 ft., a further 63 specimens measuring 60.5–133 mm. total length were collected by the writer from the same locality in 1958. Bullock and Medway also report the species.

The species is common in the torrential stretches of the Ayer Besar and the Bahru, and appears to be the only cyprinid fish occurring on the Island.

Commenting on regional variation in the colour pattern of the species, Tweedie (1961) placed his Tioman specimens under his Johore Form but pointed out that the pattern was indistinct since the specimens had been poorly preserved. He however added that in the single juvenile of the series, the pattern was clear and of the normal Johore type. The specimens now available, show intermediate characteristics between the Johore Form (Tweedie, 1961, pl. 22, fig. 2) and the Muar

River Form (Tweedie, 1961, pl. 22, fig. 4) in the presence of an incomplete anterior horizontal bar which does not reach the posterior vertical bar. Like the form described from Pahang (Tweedie, 1961 pl. 22, fig. 6) some of the specimens from Tioman have a few dark spots between the two vertical bars.

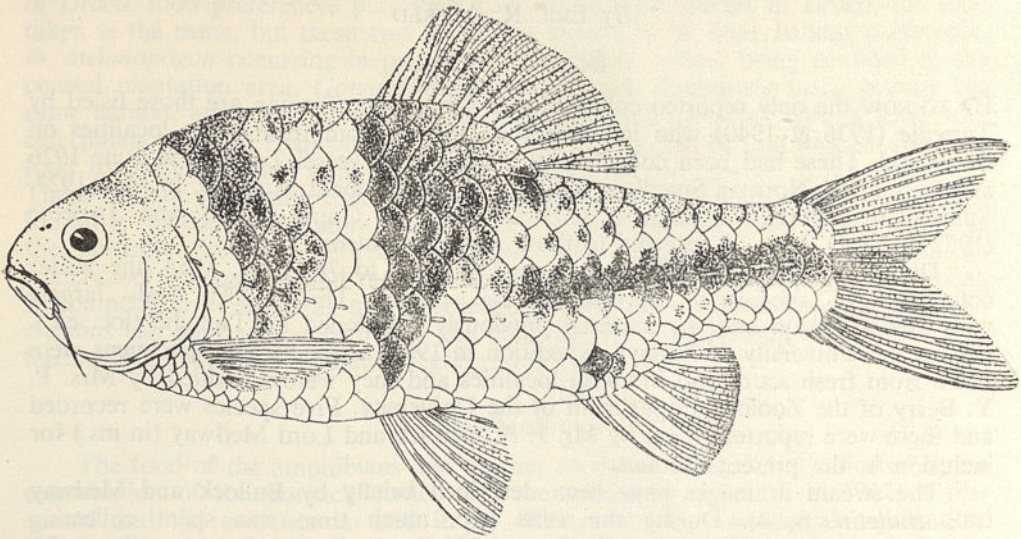

Figure 6. *Puntius lateristriga* (Valenciennes), Sungei Ayer Besar, Pulau Tioman, showing colour pattern.

Clarias nieuhofi Valenciennes

Clarias nieuhofii Valenciennes, In: Cuvier and Valenciennes, 1840, Hist. Nat. Poissons, 15:386 (locality not given).

Clarias nieuhofi Weber and de Beaufort, 1913, Fishes Indo-Aust. Archipel., 2:189; Tweedie, 1936, Bull. Raffles Mus., 12:18 (Sedagong River, Tioman Island, east coast Malay Peninsula); Tweedie, 1952, Bull. Raffles Mus., 24:88 (Tioman Island).

Clarias nieuhofii Fowler, 1938, Fish. Bull., 1:247 (Sedagong River, Tioman Island, east coast Malay Peninsula).

Prophagorus nieuhofi Hora and Gupta, 1941, Bull. Raffles Mus., 17:43 (Sedagong River, Tioman Island).

The previous Tioman record is based on a single specimen collected by Smedley from the Sungei Sedagong (= Sungei Ayer Besar). A further 5 specimens measuring 200–285 mm. total length were obtained in 1958 from the same river at an elevation of about 900 ft. Commenting (in ms.) on the *Clarias* sp. they collected, Bullock and Medway state that they were "sometimes present in quite large numbers and some 12 specimens came simultaneously to refuse in the stream near Camp II (a tributary of the S. Ayer Besar) on one night."

I agree with Hora's observation (in Tweedie, 1952: 86) that the confluence of the median fins with the caudal is not consistent in the species and that *Prophagorus* Smith is not validly distinct from *Clarias* Scopoli. In my 5 specimens, only 1 has these fins confluent.

Fluta alba (Zuiew)

Muraena alba Zuiew, 1793, Nova Acta Acad. Sci. Petrop., 7:299, pl. 7, fig. 2 (not seen).

Monopterus albus Weber and de Beaufort, 1916, Fishes Indo-Aust. Archipel., 3:413, figs. 210–211; Tweedie, 1936, Bull. Raffles Mus., 12:21 (Off Pulau Tioman, east coast of Malay Peninsula).

There is a single specimen from the *Tongkol* collection measuring 280 mm. total length. Tweedie (1936) gives the locality as "Off Pulau Tioman" but the label reads "N.E. of Pulau Tioman". This record requires confirmation.

***Aplocheilus panchax** (Hamilton)

Esox panchax Hamilton, 1822, Fishes of Ganges, pp. 211 & 350, pl. 3, fig. 9 (Bengal).

Herein recorded on the basis of the report by Bullock and Medway of specimens taken from a brackish locality. Berry confirmed (in litt.) that she had no doubt of the identification.

***Dermogenys pusillus** van Hasselt

Dermogenys pusillus van Hasselt, 1823, Algem. Konst. Letter-Bode, 1823 (2):131 (Java).

Dermogenys pusillus Mohr, 1936, Mitt. Zool. Mus. Berlin, 21 (1):39–50, figs. 4–7.

The species is common in brackish localities. 16 specimens were taken from the Tekek in 1958. Also recorded by Bullock and Medway.

***Zenachopterus beauforti** Mohr

Zenachopterus beauforti Mohr, 1926, Zool. Jahrb., 52:259, fig. 21 (Muar River and Kuala Selangor).

One specimen, a female of 107 mm. total length (excluding the lower jaw), was collected in 1958 from the brackish zone of the Tekek.

***Mugil seheli** Forskal

Mugil seheli Forskal, 1775, Descriptiones Animalium, p. 73 (Lohaja, Red Sea)

Mugil seheli Weber and de Beaufort, 1922, Fishes Indo-Aust. Archipel., 4:252.

Four specimens of 15–90 mm. total length were taken in 1958 from the brackish zone of the Bahru.

***Pranesus pinguis** Lacepede

Atherina pinguis Lacepede, 1803, Hist. Nat. Poissons, 5: 372, pl. 11 (not seen).

Pranesus pinguis Smith, 1965, Ichth. Bull. Rhodes Univ., 31:616, pls. 99, A–F, 100, A–C.

Six from the brackish zone of the Bahru and seven from the Tekek were taken in 1958. The series measures 100–118 mm. total length. The species was encountered in vast numbers in both localities.

***Apogon amboinensis** Bleeker

Apogon amboinensis Bleeker, 1853, Nat. Tijd. Ned. Indie, 5:329 (Amboina).

Apogon amboinensis Weber and de Beaufort, 1929, Fishes Indo-Aust. Archipel., 5:340.

Seven specimens measuring 58–80 mm. total length were obtained in 1958 from the brackish zone of the Tekek.

***Ambassis interrupta** Bleeker

Ambassis interrupta Bleeker, 1852, Nat. Tijd. Ned. Indie, 3:696 (Ceram and Java).

Ambassis interrupta Weber and de Beaufort, 1929, Fishes Indo-Aust. Archipel., 5:415.

Four from the brackish zone of the Bahru and a further 51 specimens from the Tekek were collected in 1958. They measure 51–95 mm. total length. The species occurred in vast numbers in both localities.

***Therapon jarbua** (Forskal)

Sciaena jarbua Forskal, 1775, Descriptiones Animalium, p. 50 (Red Sea).

Therapon jarbua Weber and de Beaufort, 1931, Fishes Indo-Aust. Archipel., 6:147.

Four juveniles, the largest measuring 15.5 mm. total length, and a larger specimen of 86 mm. total length were collected in 1958 from the brackish zone of the Tekek.

***Sillago sihama** (Forskal)

Atherina sihama Forskal, 1775, Descriptiones Animalium, p. 70 (Lohaja, Red Sea).

Sillago sihama Weber and de Beaufort, 1931, Fishes Indo-Aust. Archipel., 6:172, fig. 33.

One of 150 mm. total length was collected from the brackish zone of the Tekek in 1958.

***Selar mate** (Cuvier)

Caranx mate Cuvier, In: Cuvier and Valenciennes, 1833, Hist. Nat. Poissons, 9:54 (Pondichery).

Caranx (*Selar*) *mate* Weber and de Beaufort, 1931, Fishes Indo-Aust. Archipel., 6:207.

Eight specimens measuring 93–104 mm. total length were collected in 1958 from the brackish zone of the Sungei Bahru. Large schools were seen.

***Caranx sexfasciatus** Quoy and Gaimard

Caranx sexfasciatus Quoy and Gaimard, 1824, Voy. Uranie, p. 358, pl. 65, fig. 4 (New Guinea).

Caranx sexfasciatus Weber and de Beaufort, 1931, Fishes Indo-Aust. Archipel., 6:243.

A single specimen of 120 mm. total length was taken from the brackish zone of the Bahru in 1958.

***Pomacentrus melanopterus** Bleeker

Promacentrus melanopterus Bleeker, 1852, Nat. Tijd. Ned. Indie, 3:562 (Amboina).

Pomacentrus littoralis (nec Cuvier) Tweedie, 1940, Bull. Raffles Mus., 16:79 (Tioman Island, fresh-water stream).

Pomacentrus melanopterus de Beaufort, 1940, Fishes Indo-Aust. Archipel. 8:380.

Known from 2 specimens, 100 and 111 mm. total length, collected by Smedley from a "fresh-water stream" in Juara Bay. Tweedie (1940) listed them as *P. littoralis*.

***Salarias edentulus** (Bloch, Schneider)

Blennius edentulus Bloch, Schneider, 1801, Systema Ichthyologiae, p. 172 (not seen).

Salarias edentulus Chapman, In: de Beaufort and Chapman, 1951, Fishes Indo-Aust. Archipel., 9:328.

Two specimens, a male of 75 mm. and a female of 72 mm. total length, were collected at the mouth of the Sungei Tekek in 1958. This widely distributed species is now recorded for the first time from Malaya.

Acentrogobius ornatus (Ruppell)

Gobius ornatus Ruppell, 1828, Atl. Reise N. Afr. Fische, p. 135 (not seen).

Acentrogobius ornatus Tweedie, 1936, Bull. Raffles Mus., 12:28 (Ayer Batang, Tioman Island, east coast Malay Peninsula); Koumans, 1953, Fishes Indo-Aust. Archipel., 10:71.

Tweedie's record (1936) is based on 4 specimens of 22–53 mm. total length collected from Kampong Ayer Batang by Smedley, and identified as the present species by Dr. F. P. Koumans.

***Acentrogobius balteata** (Herre)

Vaimosa balteata Herre, 1935, Field Mus. Nat. Hist. Zool., 18 (12):419 (not seen).

Acentrogobius balteata Koumans, 1953, Fishes Indo-Aust. Archipel., 10:73.

Four specimens of this distinctively marked fish were collected in 1958 from the brackish zone of the Tekek. They measure 31.2–34.5 mm. total length and 24.6–27.0 mm. standard length. The species is new to Malaya.

***Glossogobius biocellatus** (Valenciennes)

Gobius biocellatus Valenciennes, In: Cuvier and Valenciennes, 1837, Hist. Nat. Poissons, 12:73 (Pondichery).

Glossogobius biocellatus Koumans, 1953, Fishes Indo-Aust. Archipel., 10:163.

One specimen collected in 1958 and measuring 67 mm. total length from the brackish zone of the Tekek. The process of the iris in the pupil is distinct.

***Glossogobius celebius** (Valenciennes)

Gobius celebius Valenciennes, In: Cuvier and Valenciennes, 1837, Hist. Nat. Poissons, 12:74 (Celebes).

Glossogobius celebius Inger, 1957, Fieldiana: Zoology, 36 (3):396 (key).

Two specimens of 62 and 77 mm. total length were collected from fresh-water in the Tekek in 1958. The locality was well above the brackish water limits and was near the commencement of the torrential zone.

***Glossogobius giurus** (Hamilton)

Gobius giurus Hamilton, 1822, Fishes of Ganges, p. 51, pl. 33, fig. 15 (Gangetic provinces).

Glossogobius giurus Inger, 1957, Fieldiana: Zoology, 36 (3):396 (key).

A fine specimen of 220 mm. total length was collected in 1958 from the brackish zone of the Tekek.

Periophthalmus argentilineatus Cuvier

Periophthalmus argentilineatus Cuvier, In: Cuvier and Valenciennes, 1837, Hist. Nat. Poissons, 12:191 (Waigeu).

Periophthalmus argentilineatus Tweedie, 1936, Bull. Raffles Mus., 12:28 (Ayer Batang, Tioman Island, east coast Malay Peninsula); Koumans, 1953, Fishes Indo-Aust. Archipel., 10:214.

Periophthalmus barbarus (p.p., nec Linn.) Fowler, 1938, Fish. Bull., 1:267 (Ayer Batang, Tioman Island, east coast Malay Peninsula).

Tweedie's record (1936) is based on 7 specimens of about 55–65 mm. total length collected by Smedley from Kampong Ayer Batang and identified by Dr. F. P. Koumans as the present species. A single specimen of 58.2 mm. total length was taken from the mangrove at Kampong Tekek in 1958. Bullock and Medway report a *Periophthalmus* sp. as frequent in the mangrove near their Camp I.

***Eleotris insulindica** (Bleeker)

Culius insulindica Bleeker, 1875, Arch. Neerl. Sc. Ex. et Nat., 10:107 (not seen).
Eleotris insulindica Koumans, 1953, Fishes Indo-Aust. Archipel., 10:300.

Two specimens of 99 and 108 mm. total length were obtained in 1958 from the brackish zone of the Bahru.

***Ophiocara porocephala** (Valenciennes)

Eleotris porocephala Valenciennes, In: Cuvier and Valenciennes, 1837, Hist. Nat. Poissons, 12:237 (Seychelles).
Ophiocara porocephala Koumans, 1953, Fishes Indo-Aust. Archipel., 10:343.

Four specimens of 68–170 mm. total length were collected in 1958 from the brackish zone of the Tekek. The species is collected by the local populace for food.

DISCUSSION

Crude observations made by the writer in 1958 indicate that a close parallel exists between the physical features of the Tioman streams and those of the Palau Islands in the West Pacific which are described by Fehlmann (1961). Following the zonation he proposed, it is possible to break down the major stream drainages of Tioman into four zones as follows:

The *Mangrove Zone* extending from the mouth of the streams to the level attained by the highest high tides (Plate 3). The majority of the fishes recorded were collected in this zone and they include the Hemiramphidae, Apogonidae, Sillaginidae, Ambassidae, Theraponidae, Atherinidae, Pomacentridae, Gobiidae, Eleotridae, Blennidae, Mugilidae, Carangidae and Cyprinodontidae.

The *Lower Graded Zone* extending from the level attained by the highest high tides to the lower reaches of the bedrock in the stream bottom. The fishes occurring here include Hemiramphidae, Gobiidae, Ambassidae and Clariidae.

The *Cascade Zone* extending from the lower reaches of the bedrock in the stream bottom to the upper reaches of bedrock in the stream bottom (Plate 3). This zone covers by far the greater part of the Tioman streams. Only the Clariidae and Cyprinidae occur here.

The *Source Zone* extending from the upper reaches of bedrock in the stream bottom to the source of the stream. The fish fauna appears to be restricted to the Clariidae.

The similarities in the faunal composition of the Mangrove Zone in both Tioman and Palau are not unexpected. The forms occurring here are mainly the so-called diadromous fresh-water fishes which, as Myers (1949) points out, "are distributed by sea and their presence in the fresh-water fauna is often an indicator more of the composition of the marine than of the fresh-water fauna."

In the Palaus, the absence of primary or secondary fresh-water fishes coupled with the occurrence of complementary forms is in keeping with their position as oceanic islands. In Tioman however, the presence of the two primary fresh-water fishes, viz., *Puntius lateristriga* and *Clarias nieuhofi,* immediately suggests that the island must have been connected to the mainland in the past. The occurrence of the secondary fresh-water fishes, *Aplocheilus panchax* and *Dermogenys pusillus,* could be cited as further evidence for this. Most significant however, are the similarities in the colour pattern of *P. lateristriga* from Tioman with those of specimens from the adjacent mainland of Johore and Pahang.

The recorded locality for *Glossogobius celebius* is interesting and should be investigated further. Its position is probably complementary owing to the scarcity of primary and secondary species.

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9. Introductory Report on the Terrestrial Arthropods

By J. A. BULLOCK

INTRODUCTION

The accounts of the vertebrates in this series of papers have been concerned, amongst other things, with the taxonomy of the animals recorded and their affinities with forms from Malaya and elsewhere. It is quite impossible to treat the arthropods in this way since the services of a large number of specialist taxonomists would be necessary to achieve this aim. Even if this were possible, the incidence and distribution of many of the insects of the Malayan region, even of the comparatively well-studied Rhopalocera, is so imperfectly known that it is doubtful whether many valid conclusions could be drawn. I have therefore attempted to summarise by means of a commentary and tables the principal families (or super-families)[23] recorded in the different habitats on the island and to indicate their possible role in the ecology of the habitat. This approach is by no means original, both Usinger and La Rivers (1953) and Gressitt (1954) have used it in their discussion of the insects of Arno Atoll and of Micronesia respectively, and it seems to me that this approach helps to convey a general impression of the fauna.

In dealing with the soil and litter meiofauna, I have departed from this procedure because no study of these forms has been made in Malaya and very little has been done within the Indo-Malaysian sub-region. I have therefore listed the orders found in the various samples and indicated the numbers recovered, imperfect as these data probably are.

TERRESTRIAL HABITATS

Strand (Table 1)

The sandy, open beaches at Tekek and elsewhere carried little insect life. A number of Diptera were present, including various muscoids which were feeding on refuse and other debris and which were attracted in very large numbers to the corpse of a *Varanus* lizard which had died near Camp I. Various smaller Diptera were found moving over the beach at random and were presumably finding something on which to feed. Robber flies (Asilidæ) and small æshnid dragonflies were frequently seen hunting over the beach and were observed preying on the flies, whilst various ants and lycosid spiders made short excursions from the leaf litter of the beach vegetation.

TABLE 1

Strand communities

Open beach		
Saprophages	...	... Diptera (various).
Scavengers	...	... Amphipoda, Formicidæ.
Predators	...	... Aeshnidæ, Lycosidæ, Asilidæ, Ocypodidæ (crab).
Headland beaches		
Scavengers	...	... Gryllidæ, Acarina, Formicidæ.
Predators	...	... Lycosidæ.
By dammed stream		
Scavengers	...	... Diptera, Tridactylidæ.
Predators	...	... Cicindelidæ, Libellulidæ, Aeshnidæ.

23. Identifications were usually made with Brues, Melander and Carpenter (1954) although other authors have been consulted. For the Thysanoptera, I have followed Preisner's (1949) simpler classification.

Below the rocky headlands between bays, rather more insect activity was found; small gryllids were scavenging in the shade of rocks in the intertidal zone together with a small red acarine and lycosids. Ants were also present on the beach and in one place large numbers were found in a "head down, tail up" posture. Although the ants were watched for a considerable time, no indication of what they were seeking was obtained, nor did examination of the sand reveal any difference between this and other sand in the vicinity.

A rather fuller insect scene was encountered at one spot on the beach where dunes had entirely cut off a small stream from the sea and formed a pond from which the water percolated through the dunes to the sea. Here, large numbers of flies including dolichopodids had congregated near the edge of the water and, on being disturbed, flew on to the pond and settled on a floating algal mat. Tridactylid crickets were feeding on the moist sand and several cicindelids were hunting amongst them. Several specimens of the small æshnid were hawking over the pond as was a larger libellulid.

At night, the character of the beach changed and the only forms found were ghost crabs (*Ocypode ceratophthalma*), which were present in large numbers, many amphipods, and a few ants and lycosids.

Beach Vegetation (Table 2)

In the flat areas, coconut palms were planted right down to the strand except in areas of mangrove, but none the less a characteristic beach flora formed a narrow band of vegetation in many places and with this was associated a varied insect fauna. The substrate was very sandy and no typical soil arthropods were present although the pits of numerous myrmeleonid larvæ were found, especially in sheltered areas such as beneath the rest-house (Camp I) which was built in Malay style with a clearance of 3–6 ft. These preyed on the litter fauna, notably the numerous ants but also probably the small scavenging amphipods and Blattaria. Numerous lycosid spiders were found in the leaf litter and these made short excursions on to the strand as well as hunting among the leaves.

TABLE 2

Beach vegetation

Litter and soil layer	
Scavengers	Formicidæ, Blattaria, Amphipoda, Gryllidæ.
Predators	Lycosidæ, Myrmeleonid larvæ.
Vegetation layer	
Phytophages	Chrysomelidæ, Elateridæ, Coreidæ, Tingidæ, Pyrrhocoridæ, Cynipidæ, Lepidoptera larvæ, Jassoidea, Cantharidæ, Curculionidæ, Fulgoroidea, Dipterous leaf miners.
Flower visiting	Culicidæ, Small Diptera, Lepidoptera adults, Thysanoptera (Phlæothripidæ and Thripidæ), Otitidæ, Apoidea, Other hymenoptera, Syrphidæ, Bombylidæ.
Scavengers	Formicidæ, Diptera (various), Ipid borers, Blattaria, Cerambycoid borers.
Predators	Aranea (including Salticidæ, Argiopidæ, Thomisidæ, Zodariidæ), Asilidæ, Odonata (many types), Coccinellidæ, Myrmeleonidæ.
Parasites	Ichneumonidæ, Braconidæ, Chalcididæ, Tachinidæ.

The vegetation carried a complex of insect life some of which was closely associated with individual plants. In this category may be included a small dipterous leaf miner (Anthomyidæ?) which was attacking *Scævola*, fulgoroids (?Flatidæ) on *Casuarina*, and various Thysanoptera which were recorded from the flowers of *Canavalia* (Thripidæ) and from flowering grasses (Phlæothripidæ). Other forms were less host-specific and these included numerous Acrididæ, a bright green chrysomelid, a number of plant-feeding Heteroptera, and lepidopterous larvæ.

Many plants were in flower, and were visited by a large concourse of insects; the introduced *Euphorbia heterophylla* was especially attractive and was visited by many butterflies, Hymenoptera and Diptera. The predators of this complex included many Asilidæ and Odonata. Spiders were prominent, the most frequent forms being salticids and argiopids together with the flower-squatting thomisids. Parasitic hymenoptera were also seen frequently and, although often seen on flowers, were probably hunting their hosts as well as feeding.

Mangrove (Table 3)

The small areas of mangrove appeared rather lacking in fauna and only web-spinning argiopids, numerous ants, and flies were recorded whilst a small grylloid (Ereopteridæ?) was taken on the leaves. Mangrove is, however, a characteristic breeding place for Ceratopogonidæ and, since these were frequent pests at Camp I, it is probable that they were a component of the fauna.

TABLE 3

Mangrove

Mud		
——	...	... Ceratopogonid larvæ?
Vegetation		
Phytophages	...	... Grylloidea.
Scavengers	...	... Formicidæ, Diptera.
Predators	...	... Argiopidæ.

Coconut Plantations (Table 4)

The outstanding members of the plantation fauna were two large nephiline argiopids (Plate 11) which built webs stretching from palm to palm. This web frequently carried several small males and was sometimes utilised by other spiders, including a small gasteracanthine, which presumably lived on small insects which were not taken by the large spiders. No attempt was made to assess the incidence of coconut pests, although the coconut weevil (*Rhyncophorus ferrugineus*) was frequently seen in flight and was probably responsible for considerable damage, and a lymexilid was taken at light on one occasion. Other pest forms were not recorded, although damage which might be associated with both *Brontispa* and *Oryctes* was seen.

The trunks of the trees sheltered a number of bark-dwelling forms including scorpions and aradoid bugs, whilst the fallen nuts attracted small Diptera and Coleoptera as well as providing shelter for ground dwelling forms such as millipedes. Ants again were very common and were preyed on by *Draco volans* as well as by some mammals.

TABLE 4

Coconuts

Fallen nuts		
Saprophages	...	... Diptera (including Drosophilidæ), Coleoptera (including Nitidulidæ).
Scavengers	...	... Formicidæ, Diplopoda.
Bark stratum		
Fungivores	...	... Aradidæ.
Scavengers	...	... Formicidæ.
Predators	...	... Scorpionida.
Under-storey (grass) (Also padang area)		
Phytophages	...	... Acrididæ, Thysanoptera, Lygæidæ.
Scavengers	...	... Isopoda, Decapoda, Formicidæ, Amphipoda.
Predators	...	... Cicindelidæ (adult and larvæ), Mantidæ (Padang area only).

The under-storey of the plantation was either grass or, when the plantation was uncared for, woody plants, notably an introduced *Lantana* sp. The grass supported many Acrididæ and Lygæidæ and numerous small Diptera whilst the uncared-for areas had a similar fauna to that of the regeneration (see below). The numerous tracks which crossed the plantations were a favourite haunt of cicindellid beetles, whose larvæ lived beneath the tracks. A large green form with three yellow spots on each elytron (probably *Cicindela aurulenta*) was the most frequent but a smaller black form was recorded occasionally. A third species was recorded only at Tk. Nipah.

Regeneration (Table 5)

A species of *Lantana* was the dominant form on all land which had been cleared and then allowed to revert and other vegetation was usually negligible. The flowers of *Lantana* were very attractive to a wide range of flower-visiting species and numerous butterflies, bees and flies were seen on the flower heads as well as a few Coleoptera including mordellids and lycids. Phytophagous insects included curculionids and chrysomeloids among the Coleoptera, and one of these latter, a large yellow gallerucid, was a very prominent member of the community. The species flew frequently and before sunset considerable numbers were flying simultaneously; on one occasion a flight was observed at the north end of Juara bay and for over 30 minutes a continous stream of beetles was passing overhead about 20 ft. up and flying inland along the line of cliffs. No predators successfully attacked them, although large odonates flew at them repeatedly; during the Juara flight a group of about twenty libellulids made repeated attack movements without ever seizing one.

TABLE 5

Lantana Regeneration

Litter layer		
Scavengers	...	... Blattaria, Gryllidæ, Formicidæ.
Vegetation		
Flower visitors	...	... as for shore vegetation and also: Anthomyidæ, Lycidæ, Mordellidæ.
Phytophages	...	... Chrysomeloidea, (including Gallerucidæ, Halticidæ), Lygæidæ, Curculionidæ, Elateridæ, Coreidæ, Tingidæ, Jassoidea.
Scavengers	...	... Formicidæ, Drosophilidæ, Muscidæ.
Predators	...	... Asilidæ, Reduviidæ, Aranea (including Argiopidæ and Salicidæ), Odonata (various), Cicindelidæ.

Other phytophagous insects associated with *Lantana* included flea beetles (Halticidæ), various jassoids, lygæids, coreids and tingids, together with a few phytophagous Orthoptera. The only sawfly (Tenthredinoidea) recorded was taken in regenerative growth on the headland north of Kg. Tekek. Few predators were found, apart from asilids and odonates, whilst cicindelids were common on the tracks throughout the regeneration, and a wide range of spiders, with argiopids and salticids dominant, was present.

The litter fauna was similar to that of the shore vegetation, Blattaria, various gryllids and ants being the principal forms recorded.

Padang Areas (cf. Table 4)

Although the growth of *Lantana* was typical of reverting cultivated land, in a few places open areas of long grass were found (cf. Plate 5). These carried a similar fauna to that recorded in the more cared for coconut plantations with Acrididæ the most prominent component together with many lygæids. This area was of interest in that it was the only place where a mantid was recorded on the island.

Ricefields (Ladang) (Table 6)

Apart from coconut, rice was the main crop grown and was planted on areas of cleared hill side (*ladang*) which were subsequently allowed to revert to jungle or were later planted with banana and cassava. During the period of our visit, there was only stubble on the ricefields and it was therefore not possible to discern the presence of the various lepidopterous borers which are associated with the crop in Malaya. Nevertheless, a considerable population of insects was present of which the numerically dominant group was the Thysanoptera. In addition, various homopterous bugs (Jassoidea, Fulgoroidea) were found in large numbers as were coreids and lygæids although these, together with acridids, may have been feeding on the grasses and other plants growing amongst the rice. Fungi growing on the leaves and stems of the plants were probably the reason for Psocoptera and Collembola (Poduromorpha) being found and this may also account for the presence of an oribatid mite (Oribatuloidea) in considerable numbers.

TABLE 6

	Rice (and weed grasses, etc.)
Phytophages	Phlæothripidæ, Jassoidea, Membracidæ, Acrididæ, Thripidæ, Fulgoroidea, Lygæidæ, Coreidæ.
Saprophages (and fungivores)	Diptera (various), Collembola, Oribatei, Psocoptera.
Scavengers	Formicidæ.
Parasites	Pteromalidæ, Scelionidæ, Ichneumonidæ.
Predators	Asilidæ, Aranea (various), small Coleoptera.

A wide range of predators and parasites were recorded, including ichneumonid, scelionid and pteromalid wasps in the latter category, and asilids, small predatory Coleoptera and spiders in the former. Various small Diptera were in many cases saprophytic and others were associated with litter-dwelling larvæ (see later, Soil and Litter Meiofauna).

Other Crops (Table 7)

Egg plant (*Solanum melongena*). A few egg plants were found in one spot, and these were carrying an infestation of both halticids and epilachnines.

Banana. The relatively young plantings of this crop appeared to be free of serious insect attack although a range of phytophagous insects were found, including curculionids, pentatomids and cassids. The presence of a brown lacewing (Hemerobiidæ) suggested the presence of aphids or other small plant-bugs although these were not found. The leaf sheaths were devoid of the usual arthropodan fauna possibly because of the youth of the planting.

TABLE 7

Other crops

Egg Plant		
Phytophages	...	... Halticidæ, Epilachninæ.
Banana		
Phytophages	...	... Cassidæ, Curculionidæ, Pentatomidæ.
Predators	...	... Hemerobiidæ.
Citrus		
Phytophages	...	... Eriophyidæ, Trypetidæ, Coccidæ, Other Diptera.
Durian (*rotten*)		
Saprophages	...	... Nitidulidæ, Staphylinidæ, Diptera (various).

Citrus. The small plantings of citrus at Tekek were uncared for but again supported little in the way of pests although the fruit suffered from rust mite and a scale was present on a few trees. The owner of the trees did not collect the fruit (limes) systematically; the chief use for the fruit appeared to be as a leech repellent! The rotting fruit on the ground was attacked by a number of Diptera including trypetids and these may have been the cause of initial fruit fall.

Durian. The chief pests of durian were mammalian. However, a number of insects fed in the empty husks including nitidulids and staphylinids as well as various flies.

Primary Forest (Table 8)

The forest which covers most of the island provides a number of different habitats, regardless of intimate host-plant relationships, and since most of the collecting was done in forest, considerably greater numbers of insects were recorded. The following account therefore summarises only the most prominent groups recorded.

Litter layer. The meiofauna of the litter layer is discussed in greater detail later, but certain of the larger forms were not collected in the Tullgren funnels. The litter layer was nowhere deep, except in hollows, and was usually less than an inch in depth. The majority of forms recorded were predatory or scavenging, although a number of millipedes were encountered including forms 15 cm. long, which were found in groups of thirty or more on several occasions. Of other forms, ants of many species were represented whilst grylloids (Oecanthidæ) and stenopelmatids were common, the density frequently being greater than one to the square foot. Cockroaches were frequent as were phalangids and reduviid bugs, and a sowbug (Armadilliidæ) was locally abundant. "Trilobite larvæ" (Lycidæ ♀) (Plate 11 were often encountered, both in the litter and on logs and rocks. At night additional forms, including thelyphonids, many spiders, crabs, and predaceous beetle larvæ, made their appearance.

Rotten logs. Rotten logs and tree stumps are a common feature of all tropical rain forests and have a special fauna associated with them. Termites and ants were extremely common in this habitat, as were many beetle larvæ, the most frequent being scarabæiform and elateriform types, together with millipedes, isopods and dipterous larvæ. Collembola also occurred in large numbers whilst scorpions, pseudoscorpions, centipedes, and various predaceous beetles formed the predators of the community.

Fungi formed a habitat which to some extent overlapped that of the rotting logs and these carried a large number of adult beetles as well as coleopterous and dipterous larvæ. An interesting form taken on a single bracket fungus was a large tube-forming lepidopterous larva; the tube consisted of pellets held together with silk and was 3–4 cm. in length.

Logs also formed a nest site for small sweat bees (*Trigona* sp.).

A number of flies were attracted to the logs, the most prominent being a tylid (micropezid) which wandered over the logs vibrating its fore-legs vigourously. The final stages of mating of these curious long-legged flies was observed on several occasions. The male and female faced each other and the male 'pawed the ground' with one fore-leg, gradually approaching the female. Before reaching her, the male moved round behind her, and she adopted a characteristic stance, opening her wings and bringing them forward and up. The male mounted her and coupling took place immediately; the pair remained *in copula* for some time and its conclusion was not observed.

TABLE 8

Primary Forest

Litter layer	
Saprophages and Scavengers ...	Diplopoda (various) (Sphærotheriidæ, Polydesmoidea, Juliformes, etc.), Gryllotalpidæ, Formicidæ, Stenopelmatidæ (also predatory?), Armadillidiidæ, Blattaria, Grylloidea (including Oecanthidæ), Crabs.
Predators	Reduviidæ, Phalangida, Coleopterous larvæ, Thelyphonida, Ascalaphidæ (larva), Lycidæ(♀), Aranea (various), Chilopoda.
Rotten log layer	
Saprophages	Isoptera, Collembola, Passalidæ, Coleopterous larvæ (various), Diplopoda (various), Stratiomyidæ.
Scavengers	Formicidæ, Acarina, Armadalliidæ, Elateridæ.
Predators	Scorpionida, Chelonethida, Staphylinidæ, Chilopoda.
Nest sites	Apidæ (*Trigona* sp.).
Fungus (rotten and healthy wood)	
Fungivores	Erotylidæ, Cryptophagidæ, Endomychidæ, Tenebrionidæ, Scaphidiidæ other Coleoptera, Bostrychidæ, Staphylinidæ, Tube-building caterpillars, various coleopterous and dipterous larvæ.
Rocks†	
Scavengers and lichen feeders	Machilidæ, Oniscidæ Tenebrionidæ, Formicidæ*, Chrysomeloidea, Lepidoptera (larva), Grylloidea, Psocoptera.
Predators	Chelonethida*, Dermaptera (Spongiphoridæ?), Scorpionida*, Staphylinidæ, Aranea (including Clubionidæ).

* Frequently found hiding under rock flakes.

†Tree tunks similar but with Isopteran tunnels abundant.

Tree, vine and carpet layer

Phytophages	Lepidoptera (various), Phasmida, Melolonthidæ, Coccoidea Cantharidæ, Cicadidæ, Scutellaridæ, Chrysomeloidea (various including Gallerucidæ, Hispidæ, Halticidæ), Coreidæ, Tettigoniidæ, Pentatomidæ, Dascillidæ, Mordellidæ, Gryllacridæ, Tipuloidea, Jassoidea, Cicadellidæ, Flatidæ, Grylloidea, Cercopoidea, Lygæidæ, Cynipoidea (galls), Curculionidæ, Cecidomyidæ, Apoidea, Cetoniidæ.
Wood-boring	Cerambycoidea, Brenthidæ, Siricoidea, Isoptera.
Scavengers and Saprophages ...	Formicidæ, Dolichopodidæ, Calliphoridæ, Blattaria, Tenebrionidæ, Muscidæ, Bibionidæ, Celyphidæ, Otitidæ.
Predators	Cicindelidæ, Panorpidæ, Reduviidæ, Dryinidæ ♀, Asilidæ. Ichneumonidæ, Pompilidæ, Sphecoidea (Bembicidæ?), Miridæ, Dermaptera, Lampyridæ, Aranea various (Argiopidæ, Eusparassidæ, Clubionidæ, Mygalomorpha, Salticidæ, etc.).

Rock faces. The numerous boulders (Plate 12) and large rocks formed a special habitat on which lichens, mosses and a small creeper provided cover for a wide variety of insects, and this habitat was very similar to that of the bases of trees on which a similar vegetation flourished. The characteristic fauna included a large machilid, several small beetles, a cricket, lepidopterous larvæ, tetrigids, isopods and ants, and these were preyed on by various spiders, including ant-mimicing clubionids, dermapterans, staphylinid beetles, scorpions and pseudoscorpions. Rock flakes which were still associated with the matrix formed a sheltered habitat under which ants nested, and which also provided cover for scorpions, pseudoscorpions and other photo-phobic forms.

The curious stalk-eyed flies (Diopsidæ) were frequently found in large numbers in the vicinity of these rocks, and very rarely away from them, but no reason for this close association could be found. The species was not associated with any form of vegetation, contrary to the habit of many of this family which occur in short vegetation, especially grass; Curran (1945) has suggested that the stalked nature of the eyes is an adaptation to seeing round the far side of grass leaves. In this instance, the somewhat waisted abdomen and the hovering flight suggested a small wasp (e.g., Stenogasterinæ) and the stalked eyes enhanced this impression as they resembled the thickened antennæ in both shape and posture.

Tree trunks differed from the rocks in that isopteran earth passages were very frequent, and also in the presence of cicada castes. Cicadas themselves were remarkably abundant, as were several species of ants.

Vegetation. As might be expected, the insects associated with vegetation were exceedingly numerous. One of the most frequent of the insects of the carpet and herb layers was a scorpion-fly (Panorpidæ) of which large numbers were seen and a good series collected. This form does not appear to be common in mainland forests and its appearance in large numbers on Tioman suggests the absence of some controlling factor. Other prominent members of this layer were a small, bright blue, oval celyphid and an orange and black cicindelid; small Dolichopodidæ were also seen frequently. Various Chrysomeloidea were found in large numbers, often apparently linked with a few species of host plants, although a bright blue gallerucid was common everywhere. Of the other forms recorded it is not possible to pick out any for special mention, especially since many were taken in flight.

Cecidomyids were taken on several occasions on spiders' webs where they were resting in large numbers without being molested by the resident spider. This habit has been recorded in several tipulids (cf. Tams, reported in Edwards, 1934, on *Limonia seychellarum* Edw.) but usually in these instances relatively few insects

are involved and they settle in a horizontal line. As can be seen from the photograph (Plate 12), the cecidomyids rest all over the web. The significance of this practice is not known, and although Hendrickson (pers. comm.) believes that in tipulids the aggregation has sexual significance, prolonged observation of the webs failed to reveal any mating behaviour in these midges. In contrast to the tipulid aggregations, there was little activity on the webs, and it may be that the midges use the webs as a means of eluding predators.

Gunong Kajang

The investigation of the fauna of the higher land around Gunong Kajang was severely hampered by the very wet weather and the short duration of the trip. The general impression was that, within the primary forest, the fauna was much the same as at lower altitudes, although many types were far less abundant; the only noticeable absentees were the water associating forms. Only single specimens were collected of the panorpid and of the orange and black cicindelid, whilst the litter-dwelling grylloids and stenopelmatids were noticed far less frequently; the same observation is generally true of other forms. Few new forms were collected with the exception of some small diptera (including a few empids) which were found flying about over a damp, mossy rock near Camp V.

Higher up on G. Kajang, the fauna was conspicuously depleted; very few forms were recorded here, although on the summit many insects were seen in flight. At dawn of the night we spent on the summit (Camp VI) large cerambycids, curculionids, scarabæids and chrysomeloids as well as several smaller Coleoptera were seen in flight, while many small Diptera including a swarm of psychodids were also present. Insect activity at the summit must have been great at all times, as a swarm of large libellulids as well as a number of Swiftlets (*Collocalia* spp.) were very fully occupied.

Arthropods associated with *Rafflesia hasselti* (Table 9)

Rafflesia hasselti was found on several occasions on lianes. The flowers were not product at ground-level (cf. Henderson, 1951: 425–426) but emerged from the stem some six to twelve feet above the ground, the buds having the general shape of a cabbage heart and the flower having a span of 12–14 in. The buds of this plant are believed by the islanders to have medicinal value, and are collected and sold locally and on the mainland.

TABLE 9

Rafflesia (Inflorescence)

Alive (Flower visitors)	...	Sciaridæ, Muscidæ, Calliphoridæ.
Dead (Saprophages, etc.)	...	Scolopendroidea, Homopteran nymph, Acari, Dipsocoroidea, Collembola (Poduromorpha), Lathridiidæ?

The flowers of *Rafflesia* (Plate 14) are reported to be attractive to carrion infesting flies, and a specimen kept in camp certainly appeared to attract these flies, large calliphorids and muscids alighting on and near it, as did a small nematoceran fly, probably Sciaridæ. The cause of this attraction appeared to be visual stimulation since no fœtid odour was apparent, as may be found in certain diptera-pollinated asclepiads such as *Caralluma* (cf. Bullock, 1963), although Holttum (1954) reports that a strong odour is produced in some species of *Rafflesia*.

A number of dead buds were also found, and examination of one of these revealed a small arthropodan community of saprophages and predators to be well-established. These included small beetles, mites, poduromorph collembolans, dipsocoroid bugs and scolopendroid centipedes. It would be interesting to know what induced these forms to climb the twelve or more feet to reach this specialised and rather peculiar habitat.

Cave faunas (Table 10)

Of the several caves and overhangs visited on the island, only those which supported a population of Black-nest Swiftlets, *Collocalia maxima*, carried any typical cave fauna. In one such cave, Gua Sinah, the floor was littered with droppings and the rotting feathers of birds. This accumulation provided food for a number of dipterous larvæ, some small tineid moth larvæ, ants and small beetles, as well as a large number of Acarina. The walls carried a number of juliform millipedes and several large rhaphidophorine cave crickets, whilst a large striped spider (Eusparrasidæ?) was found in several crannies. The nests of the swiftlets yielded two types of Acarina, one of which was probably ectoparasitic and the second a scavenger. In addition, two liphistiid webs were found in the entrance passage; one contained a live spider, which unfortunately escaped, and the second was empty. A second cave nearby added little to the list, except for a large Amblypygi (Charontidæ), and a small crab.

TABLE 10

Cave fauna (*Collocalia maxima*)

Guanophages ...	... Acarina, Coleoptera, Tineid larvæ, Dipterous larvæ.
Scavengers ...	... Formicidæ, Rhaphidophorinæ, Collembola, Juliform Diplopoda, Staphylinidæ.
Predators ...	... Liphistiidæ, other Aranea (Eusparrasidæ), Amblypygi, crab.
C. maxima nests ...	... Acarina.

Examination of the guano from these two caves yielded numerous mites and a few other forms including tineid larvæ, dipterous larvæ, staphylinid beetles and a collembolan. This contrasts strongly with guano collected from a similar birds'-nest cave on Pulau Tulai by Lord Medway and D. R. Wells, in which there were very few mites, and numerous dipterous larvæ. The constitution of the guana appeared to be the same, with the sclerites of winged ants and a few beetle elytra forming the only identifiable food remains. It was however noted at the time that the Tulai samples were much darker in appearance than those from the main-island caves. These differences may be related to the natural moisture content of the caves.

AQUATIC HABITATS (Table 11)

A wide range of aquatic habitats was present on the island and these carried a considerable diversity of arthropodan forms. In this section I have also included those forms which are usually associated with water, e.g. Plecoptera adults, since these are more readily considered in relation to water than the ecology of the surrounding country.

The Sea and Mangrove Areas

On the open sea, only marine Gerridæ (Halobatinæ) were found but in the small bays, and especially amongst the mangrove on P. Tulai, marine Veliidæ (Haloveliinæ) were also present.

Coastal Plain

On rivers which flowed directly into the sea, such as the S. Ayer Besar at Tekek, the only insect life recorded was gerrids, the Halobatinæ overlapping to some extent with other Gerridæ. Truly aquatic insects were not taken, probably due to the river "backing-up" with the rising tide and much of the meander being subject to a certain amount of salinity. In these conditions, only amphipods, prawns and crabs existed and these forms also occurred in pools which were flooded at high-tide.

However, where fresh-water ponds had developed as a result of the river being dammed by dunes, a flourishing insect community had become established as in the pond shown in Plate 13. Here a floating algal mat harboured much of the insect life and very few animals were present on the sandy bottom. The insectan community were all juvenile and included a range of Odonata and a few Ephemeroptera, as well as numerous Chironomidæ of which some were living within the algal cells. In addition both culicines and anophelines were present in small numbers; crustacea were mainly represented by Cladocera.

The surface fauna included gerrids, veliids and hydrometrids whilst the various Diptera on the shores of the pond frequently flew onto the mat and joined these surface forms. Above the pond, predators consisted of odonates, and tetragnathine spiders had built their webs on all overhanging vegetation. Variations on this complex occurred in other stream meanders which were not subject to tidal encroachment.

Cleared Areas

The streams running through cleared hillside areas were rather depleted in their fauna, one examined at Tekek only containing bætid larvæ and possibly a naucorid. (This last escaped capture despite my efforts and, if the sight identification is correct, was the only truly aquatic hemipteran recorded.) At Mokut, a stream had a greater fauna, consisting mainly of dipteran and plecopteran larvæ, but even so comparison with a similar forest stream (see next section) reveals considerable depopulation.

Primary Forest

Above the coastal plain, the streams were usually rocky and more or less precipitous. In the more torrential parts of the streams little in the way of insect life could be found, although gerrids were present in all environments. Otherwise the only forms which could be found were larval heptagenids and libellulids whilst trichopteran adults were seen "dancing" over the rapid waters.

In the slower running parts of the river where rocks were less water-worn and some sedimentation had taken place, more forms were found, Trichoptera, Odonata, Ephemeroptera and Diptera all being represented. In the calmer backwaters a greater diversity occurred; the families differed from those in the main river and aquatic cockroaches and small beetle larvæ (probably Helodidæ) were recorded. The smaller feeder streams, which were often overgrown with vegetation and, except after rain, carried only a very small amount of water so that small pools formed, again showed some change in fauna, the larger anisopteran nymphs disappeared whilst nemourids, perlids and tipulids appeared. This habitat was also the only one from which mesoveliids were recorded.

TABLE 11

Aquatic communities

Sea and Mangrove		
Predators and Scavengers	...	Gerridæ (Halobatinæ), Veliidæ (Halovelinæ).
River meanders subject to tidal influx		
Scavengers ...	...	Amphipoda, Isopoda, Crabs, Prawns, Gerridæ.
Fresh-water Ponds (Coastal)		
Phytophages ...	...	Cladocera, Chironomidæ.
Scavengers ...	...	Bætidæ, Culicidæ.
Predatory ...	...	Gomphidæ, Aeshnidæ, Megapodagrionidæ, Libellulidæ.
Surface feeders	...	Gerridæ, Veliidæ, Hydrometridæ.
Above surface (predators)	...	Argiopidæ (Tetragnathinæ), Odonata.

Stream through regeneration

Scavengers	...	Simuliidæ, Limoniidæ, Cænidæ, Hydroptilidæ, Bætidæ, Blepharoceridæ.
Predatory	...	Naucoridæ?
Surface	...	Gerridæ, Veliidæ.

Forest stream (rocky torrential)

Scavengers	...	Heptagenidæ.
Predator	...	Libellulidæ.
Water surface	...	Gerridæ.

Forest stream (rocky, slower flowing)

Main stream

Scavengers	...	Hydropsychidæ, Heptagenidæ, Simuliidæ.
Predatory	...	Amphipterygidæ.

Back waters

Scavengers	...	Hydropsychidæ, Bætidæ, Potomonthidæ, aquatic Blattaria, Chironomidæ, Simuliidæ, Cænidæ, Helodidæ?
Predators	...	Corduliidæ, Gomphidæ.
Water surface	...	Gerridæ.

Slow flowing stream (over small, unworn stones)

Scavengers	...	Heptagenidæ, Perlidæ, Simuliidæ, Nemouridæ, Tipulidæ (or predatory?), Hydropsychidæ, Phrygænidæ, Bætidæ, Chironomidæ.
Predators	...	Epallagidæ, Amphipterygidæ.
Water surface	...	Mesoveliidæ, Gerridæ, Veliidæ.

Slow flowing stream (sedimentary bottom)

Scavengers	...	Perlidæ, Atyidæ (prawn), Heptagenidæ.
Predatory	...	Corduliidæ, Gomphidæ.
Water surface	...	Gerridæ.

Seepage Pools

Predatory	...	Corduliidæ, Libellulidæ, Cœnagrionidæ, Dytiscidæ.
Water surface	...	Veliidæ.

Rock pools (fresh-water, leaves)

Scavengers	...	Small Blattaria.
Predators	...	Dytiscidæ.

Rock Pools (on water slide)

Scavengers	...	Dixidæ, small Coleoptera, Heptagenidæ, Hydropsychidæ, Peltoperlidæ.
Predators	...	Amphipterygidæ, Epallagidæ
Water surface	...	Gerridæ, Veliidæ.

Rock Pools (rain water and sea spray)

Scavengers	...	Culicidæ, Cladocera.

Nepenthes pitchers (Kajang) and tree-holes

Scavengers	...	Culicidæ.

Although the majority of streams were rocky, in some areas on the eastern side few rocks were present and the streams flowed sluggishly over a silty bottom. Most rock-living forms disappeared and the fauna was greatly reduced, only a few Odonata, Ephemeroptera and Plecoptera being present. Rather similar conditions, although with a higher humus and mud content, existed in various seepage pools and puddles, and in these the fauna was still further restricted and only a few odonate larvæ were found, together with small predaceous beetles. Since all these

forms are predaceous, it would be expected that some prey would be present. However, only mosquito larvæ were recorded and it is possible these together with insects which fell into the water formed the entire diet. This might be supplemented by cannibalism.

Rock Pools

On the main stream of the S. Ayer Besar, the large boulders often contained small hollows in which rain-water and leaves accumulated (Plate 14). These contained large numbers of small aquatic cockroaches and beetles. The basic attraction may have been small dipterous and other larvæ which were living on the dead leaves above the level of the water.

Two other types of "rock-pools" were examined. The first of these, at Kg. Lalang, lay half-way down a steep cliff down which water was running ("water-slide"). The water accumulated on a ledge in a small, shallow pool before over-flowing and continuing down the cliff. This small pool contained a variety of forms which resembled to some extent the feeder streams, in that only zygopteran larvæ represented the odonates, whilst hydropsychids, dixids and very small beetles were also present. Even in such a small and relatively inaccessible area both veliids and gerrids were present on the water.

The second type of pool was coastal, occurring in hollows on rocks near the high-tide mark but presumably deriving most of its water from rain although the water tasted distinctly brackish. The only forms recorded, albeit in some numbers, were mosquito larvæ and Cladocera.

Pitchers and Tree Holes

One final type of aquatic habitat which deserves mention is the small accumulations of water in tree-holes, *Nepenthes* pitchers, etc., which occasionally carried mosquito larvæ. These were relatively few however and the majority of such habitats were devoid of insect life.

Water-associating Insects

A considerable number of insects were found along the streams and rivers in the forest area although not actually living in or on the waters. These were not essentially confined to the river areas but were taken in far greater numbers here than elsewhere. Chief among these were the Odonata, and especially the Zygoptera, which were present in large numbers and considerable diversity. Trichoptera were recorded several times as were a few isolated Plecoptera but throughout our stay not a single adult Ephemeroptera was seen. Numerous Diptera including dolichopodids, asilids and tabanids were caught along the streams as well as many smaller flies which were foraging on the rocks and amongst damp leaves at the edge of the rivers.

The lichen-covered boulders on the main course of the S. Ayer Besar in the forest were especially well populated with small Diptera which rested on them, and gave the impression of sporulating bodies of the lichen until disturbed. The semi-aquatic tetrigids were also present in large numbers and these extended their range down into the *ladang* areas; and a small green cicindelid was only recorded in close proximity to the water both on the boulders and on foliage over-hanging the streams. Many spiders (chiefly Tetragnathinæ) had spread their webs over the water courses and preyed on the numerous forms which used the stream as a flight-way.

In the coastal areas, little was recorded apart from odonates and spiders, although a number of insects including tabanids and ants used the stream as flight-ways. Chironomid adults were observed in considerable numbers over a fresh-water pool at Tekek at night.

ECTOPARASITES AND BITING FLIES

Ectoparasites (Table 12)

The mammals and birds which were collected were with few exceptions examined for ectoparasite infestations. The intensity of examination was, however, somewhat variable. Specimens collected near to Kg. Tekek were usually examined with a binocular microscope; those collected on G. Kajang were only examined by eye. Much of the work of collecting was performed by Mr. C. K. Ng, and by Mr. B. L. Lim during his stay on the island, although all members of the party participated from time to time. A detailed account of the Acarina collected appears later in this volume (Nadchatram et al.) whilst the Siphonaptera are listed in Appendix 1 from data supplied by Dr. R. Traub.

Of the mammals examined, only three species were "clean" and these are all arboreal forms, namely *Ratufa, Petaurista* and *Cynocephalus,* all of which were taken in small numbers. The two insectivores carried acarine infestations only whilst the four Chiroptera were mainly subject to ectoparasitic diptera although acarines were recorded from both *Pteropus* and *Cynopterus.* The only primate examined, *Tupaia,* carried both acarines and a few fleas, and the only ungulate, *Tragulus,* was attacked by ixodids, trombiculids and apterous hippoboscids. Amongst the rodents, the various species of *Rattus, Sundasciurus* and *Callosciurus* were subject to attack by many acarines and by fleas; C. *notatus, R.* sp. *tiomanicus* and *R. surifer* also yielded Anoplura (Hæmatopinidæ in the first two cases). In addition a small mallophagan was recorded from a single specimen of *R.* sp. *tiomanicus.* The other three rodent genera showed various gaps in the parasite pattern; *Atherurus* carried only acarines, *Lariscus* had acarines and fleas, and the small flying squirrel, *Iomys,* had fleas and dixodids only. Several specimens of *Rattus* were also found to have pseudoscorpions clinging to their fur, but these were presumably nest-dwelling forms which had either accidentally or intentionally allowed themselves to be carried out of the nest. A single rat's nest, believed to be of *R. surifer,* contained many of these arachnids as well as a phalangid (Sironidæ) and a juliform millipede.

The birds were mainly free of ectoparasites, the majority carrying only a few Mallophaga, mainly Philopteridæ. The two species of *Fregata,* however, were heavily infested with mallophages, whilst *F. andrewsi* also carried a few hippoboscids.

Biting Flies

Three families of biting flies were recorded on the island. Ceratopogonids, including *Culicoides* sp., were somewhat common along the coast, especially near mangrove although rarely, during our visit, in such numbers as to make life miserable. Tabanids were common, especially in the forest, and, as has been noticed elsewhere (see Dunn later), were readily attracted to man. Culicidæ were very common in the coastal and cleared areas, although in the primary forest man-biting forms were rare. Apart from the *Anopheles* spp. which have been summarised by Warren (see later) the most frequently noticed form was an *Aëdes* (assumed to be *A.* (*Stegomyia*) *albopictus*) which was common in the coconut plantations. Although many simuliid larvæ were common in the forest streams, no case of adults biting man was recorded.

TABLE 12

Ectoparasitic arthropods recorded from the mammals and birds.

	Acarina					Diptera			
	Trombiculidæ	Ixodidæ	Other Acari‡	Mallophaga	Anoplura	Nycteribidæ	Streblidæ	Hippoboscidæ	Siphonaptera
MAMMALIA									
Insectivora									
Crocidura malayana	+	+							
Hylomys suillus	+	+							
Dermoptera									
Cynocephalus variegatus									
Chiroptera									
Pteropus hypomelanus			+			+			
Cynopterus brachyotis		+*	+			+			
Eonycteris spelæa						+	+		
Rhinolophus sp.							+		
Primata									
Tupaia glis	+	+	+						+
Rodentia									
Petaurista petaurista									
Iomys horsfieldi		+							+
Ratufa bicolor									
Callosciurus notatus	+	+							+
C. nigrovittatus	+†	+			+				+
Sundasciurus tenuis	+	+	+						+
Lariscus insignis	+†	+							+
Rattus sp. *tiomanicus*	+	+	+	+	+				+
R. exulans	+	+	+						
R. surifer	+	+	+		+				+
R. sabanus	+	+	+						+
R. cremoriventer		+	+						
Atherurus macrourus		+	+						
Ungulata									
Tragulus napu	+	+						+	
AVES									
Fregata andrewsi				+				+	
F. ariel				+					
Lonchura striata				+					
Graculus religiosa				+					
Aplonis panayensis				+					
Copsychus malabaricus				+					
Dissemurus paradiscus				+					
Collocalia maxima				+					

*Argasidæ. †Also Chelyetidæ. ‡Mainly Læapidæ.

SOIL AND LITTER MEIOFAUNA

The soil and litter fauna of the Malaysian region seems to have received even less attention than has the other insectan fauna. Dammerman (1925 and 1937) described some of the macrofauna of the litter layer of various habitats in Western Indonesia including Sumatra and Java, but his technique was not intended to reveal the smaller forms, whilst Soehardjan (1957) has given some account of the Javan fauna. In this brief study, samples of both soil and leaf litter were extracted by means of rough Tullgren funnels, 10 in. in diameter, with a mosquito gauze disc 8 in. in diameter placed within them. The sample to be extracted was placed in the centre of the gauze leaving an air space around the outside to allow the escape of moist air and prevent condensation within the funnel. The funnels were kept in racks under the rest-house (Camp I) and the fauna was collected into 3×1 in. specimen tubes containing 70% ethanol. No repellent agent was used; samples were left to dry slowly, over a period of a week in most cases.

Soil samples were usually collected with a 2 in. diameter soil augur to a depth of 5 in., two such samples being bulked in each case. An exception to this was made on G. Kajang, the samples being taken with a metal trowel, but the same sampling pattern was maintained. Litter was collected from approximately one square foot, although this area was varied depending on the depth of litter sampled. In many cases the leaf litter occupied too great a volume to be placed in one funnel and often two or even three funnels were used. Soil samples were generally divided between two funnels.

After extraction, the samples were stored in 70% ethanol and were later sorted and identified as far as possible under a binocular microscope. When samples were clean, the contents of the tubes were shaken and tipped into a dish and examined straight away but if much soil or detritus had fallen into the tube a slightly more complicated technique was used. The ethanol was decanted into a dish and examined, and magnesium sulphate solution (S.G. 1.2) was added to the residue and the tube shaken vigorously. The soil was then allowed to settle and the fluid containing the floating arthropods tipped off. As a precaution, the residue was then treated with benzene and water, the tube again shaken and, after allowing the benzene and water to separate, the interface was examined for any arthropods which had been missed in the previous extraction.

Sampling Areas

Samples were taken from all the major ecological habitats with the exception of the coastal vegetation, but the greatest emphasis was placed on the primary forest where four samples were taken of soil and five of litter. Single samples were taken from each of the major ecological zones on G. Kajang (see General Introduction), except that leaf litter was not taken from the cleared summit or from the open elfin forest where no proper litter layer was apparent. In the cultivated areas, samples were taken from the rice-growing area, the coconut plantation and the area of regeneration as well as from the jungle edge. In addition, a litter sample was taken from an accumulation of leaves on a rock ledge by the river and a soil sample was taken from beneath an overhanging rock.

Forms Recorded

Crustacea. The crustacea were represented by members of two classes, Copepoda and Isopoda. Minute harpacticid copepods were found in a number of soil, as well as litter, samples and appeared to be generally distributed throughout the forest area. However, the vast majority occurred on G. Kajang and this is probably due to the moister conditions on the mountain. The group, according to Kuhnelt (1961) and others, is confined to water films on leaves and soil particles, and the generally damp conditions would thus be beneficial.

Isopoda were typical of the litter layer and both Armadillididæ and Oniscidæ were recorded, there being no indication of preferences within the forest.

Myriapoda. All four classes of myriapods were recorded in both soil and litter sample. Chilopods were poorly represented and the majority of forms were referable to the Geophilomorpha although a scolopendrid was also taken. The Diplopoda were better represented especially in the litter layer, and many different forms including oniscomorphs and juliforms were recorded, whilst one sample contained juvenile ?polyxenids. Pauropoda were not common but occurred in both soil and litter zones; Symphyla (probably Scolopendrellidæ) were commoner but similarly showed no preference.

Hexapoda: Apterygota. Diplura were represented in the soil by both campodeids and japygids, but in the litter layer only two specimens of the former family were recorded. Collembola, as might be expected, were amongst the commonest soil and litter forms. The majority of forms were referable to the several families of Arthropleona but a few Symphypleona were taken, especially in the litter layers. The range of forms included all stages of adaptation to a subterranean life. Protura were poorly represented whilst the Thysanura were represented by a single machilid taken amongst litter.

Exopterygota. The exopterygotes were generally poorly represented. The Orthoptera included only two small gryllids and Blattaria were obtained from two litter samples only; this scarcity is almost certainly due to their being able to escape during collection of the litter samples. Of the others, Isoptera were poorly represented, and Psocoptera were infrequent although occurring in both leaf and soil samples whilst Thysanoptera occurred in litter only. Various Hemiptera were obtained including a number of dipsocoroid bugs whilst the remainder were mostly immature Auchenorrhyncha.

Endopterygota. The majority of endopterygotes recorded were beetles or flies, although ants were frequent especially in the forest litter and two small lepidopterous larvæ and an adult chalcidoid wasp were found in the G. Kajang litter samples. The recording of alate adults always presents a problem, since they could easily be animals which fell into the funnels during extraction. For this reason, ipid wood-borers, which were common about the rest-house, were rejected in all the samples. The adult Diptera recorded from a heterogeneous group and although some may have fallen into the funnels others probably emerged from puparia in the samples and the several apterous adults (?Mycetophilidæ) recorded are typical litter-living forms. The larvæ again were fairly heterogeneous and many were not identifiable, although stratiomyids, chironomids and sciarids were present in the litter. With the exception of the Ipidæ, the adult Coleoptera were mainly staphylinids together with a few clavigerids, pselaphids and other small forms including some with setate wings, all of which may be considered as typical litter and soil types. Coleopterous larvæ were at times very numerous, the most frequent form being a typical campodeiform larva (?Staphylinidæ) but a few apodous curculionids and other types were recorded as well.

Arachnida. With the exception of acarines, no arachnids were found in great numbers. Microthelyphonids (Palpigradi) were found in two soil samples whilst pseudoscorpions were found in one soil sample and several litter samples. Single specimens of phalangids (2 Laniatores, and 1 Sironidæ?) were taken in three soil samples, and several small spiders were found, mainly in the litter layer. It is probable that both these groups are rather poorly represented in the sample due to their ability to escape both during collection and during extraction. The Acarina were the most abundant in nearly all samples and a number of families were represented of which the majority belonged to the Orobatei and Trombidiformes.

Non-arthropodans. Very small gastropod snails (possible juvenile *Microcystina*) and several oligochæte worms were recorded, the latter chiefly in the litter samples.

The Samples (Tables 13 and 14)

Cultivated Land. The samples taken on cultivated land of all sorts including regeneration, showed a somewhat depleted fauna. In the coconut plantation, the soil was virtually devoid of life, only beetle larvæ and mites being recorded, whilst the litter was scarcely better, with a small bug and two Psocoptera in addition to the mites and beetle larvæ. In the rice-growing area, rather more life was present, with many mites dominating the fauna of one soil sample, together with a very few ants, collembolans, beetles, flies, and worms. The litter contained many mites and collembolans, together with a symphylan, several Diptera and a staphylinid. The presence of a small bug and of phlæothripids is obviously associated with the rice field fauna. On the regenerated land, the soil fauna was more varied with typical soil dwellers such as geophilomorph centipedes, small millipedes (?Polyxenidæ) and a proturan appearing. The leaf litter community was not particularly large with only mites present in numbers.

Primary Forest. The two soil samples taken at the forest edge showed little difference from that on the regeneration. One sample contained numerous mites, one collembolan and a campodeid, whilst the second was chiefly of interest in that it contained two Harpacticidæ, a pseudoscorpion and a markedly increased number of Collembola. A sample taken under an overhanging rock in this locality showed a very reduced fauna, only two mites and a nymphal bug being recorded. This is hardly surprising, since the soil was very dry and dusty and probably was rarely wetted.

At about 500 ft. a.s.l., a single soil sample was taken on level ground and this showed greater diversity than previous samples, with diplopods, symphylans and a japygid present, together with relatively large numbers of collembolans, mites and beetle larvæ, whilst the only specimen of Sironidæ was taken here.

In the region of Camp II, three soil samples and five litter samples were taken. The first soil sample contained a very poor fauna, although a japygid was included. Both the other samples contained a large number of beetle larvæ, the majority of which were typical campodeiform larvæ, but with a sprinkling of a curculionid type. Symphyla were well represented in one sample which also contained a microthelyphonid, a mygalomorph spider and a proturan. The other of these two contained at least ninety-two beetle larvæ, as well as appreciable numbers of mites and collembolans. The leaf samples showed even greater diversity, with very large numbers of mites in all of them and a high collembolan population in all save one. Pauropods appeared in two samples and harpacticids in four and between them these five samples almost completely covered the range of litter dwelling orders recorded. Ants were present in four, and prominent in two, samples, whilst termites, Thysanoptera and Diplura (Campodeidæ) were all represented in one sample.

A "special" habitat examined in this region was an accumulation of leaves and humus on a rock ledge. This yielded a large number of beetle larvæ, over twenty mites, a few fly larve, a collembolan and two harpacticids.

The soil and litter samples taken in the different zones on G. Kajang showed some differentiation from those taken at 1,000 ft. The count of harpacticids was greatly increased especially in the topmost zone, a possible result of the damper conditions, and the fact that these samples were taken in rain may have been a contributory factor. The Collembola were markedly reduced, especially in the litter layer, as were also the beetle larvæ and of these the campodeiform larva, which formed the bulk of the numbers at 1,000 ft., was absent.

TABLE 13

The soil fauna

	Coconut	Ricefield		Regeneration		Forest edge		Camp II 1,000 ft.			500 ft.	Under rock overhang	Gunong Kajang Summit	Moss forest	Elfin forest	Bamboo forest	Primary forest
No. of samples ..	1	1	2	1	2	1	2	1	2	3	1	1					
Copepoda ..							2						15	5		1	
Isopoda ..				2													
Chilopoda ..					2								2				
Diplopoda ..				5					2		1				4		
Pauropoda ..													2				
Symphyla ..								1	6		2						
Diplura ..						1		1			1				2		
Protura ..					1				1					1			
Collembola ..			4	7	4	1	15	1	6	12+	30		3	4	9		1
Orthoptera ..										1							
Isoptera ..															2		
Psocoptera (apterous)										1			1	1			
Hemiptera ..				3			1		2	3		1		2		3	
Diptera adult ..						1					1		1		2	2	
larvæ ..									1		2		2	1		3	
Coleoptera adult ..			1	1	1		1	1	2		7		2		1	2	4
larvæ ..	2		2	8	1	2	1	3	42	92+	27		3	4	3	3	1
Formicidæ ..		1	1		1			1	3	1	5		1	1		5	7
Chelonethida ..							1										
Microthelyphonida									1						1		
Aranea ..									1					1			
Phalangida ..							1		1		1						
Acarina ..	2	M	7+	23	25	M	17		22	20+	36	2	24	30	19	M	3
Gastropoda ..				1													
Oligochæta ..		2		1													

+ = Rather more than the indicated number.

TABLE 14

The litter fauna

	Coconut	Ricefield	Regeneration	Camp II 1,000 ft.			Gunong Kajang			
							Moss forest	Bamboo forest	Primary forest	Rock ledge by river
No. of samples ..	1	1	1	1	2	3	4	5	1	1	1	1
Copepoda ..				1	2		2	1	1		8	2
Isopoda ..				1	1		1	2	2	1	2	
Chilopoda ..								3				
Diplopoda ..				7			2	6	3	2		
Pauropoda ..							3	2				
Symphyla ..		1		1	1		4	1		2		
Diplura ..							2					
Protura ..				1								
Collembola ..		M	2	28	41+		58	VM	10	1	10	1
Thysanura ..				1								
Orthoptera ..						1						
Blattaria ..				2			4					
Isoptera ..							11					
Psocoptera ..	2				1							
Hemiptera ..	1	3	1	2	4		6					
Thysanoptera ..		4					11					
Lepidoptera (larvæ)									2			
Diptera												
adults ..				2	3		1	4	2	3		
larvæ ..		8	3	40	12		15	3	4	2	3	8
Coleoptera												
adults ..		1		4	5	1	6	7	6	4	4	
larvæ ..	1		3	6	11		4	4		2	1	40+
Formicidæ ..				5	3		30	20	10	3	2	
Chalcidoidea ..										1		
Chelonethida ..				3			1	4	2			
Aranea ..			1	2	1		4	2			1	
Acarina ..	12	VM	26	75+	73+	VM	100+	VM	50+	42	44	20
Oligochæta ..				6	4		2	3				
Gastropoda ..			1				1					+

+ = Rather more than the indicated number. M = many, i.e. over 100. VM = very many.

DISCUSSION

The fauna of Pulau Tioman presents considerable diversity of form and few orders and families which are normally found on the Malayan mainland are not represented. There is, however, a notable imbalance apparent which will become more well defined as the specific representation is worked out. An outstanding example is the presence of the panorpid which was one of the commonest insects of the herb layer of Tioman but is encountered infrequently on the mainland. Similarly, although aquatic insects were well represented, the cryptoceratan Heteroptera were virtually absent and aquatic Coleoptera were poorly represented. Amonst the terrestrial forms, a number of forms including reduviids and mantids were decidedly less abundant than on the mainland whilst others, including some Grylloidea and various Coleoptera were more frequently encountered. However, even where groups were very abundant, there was a general impression of a paucity of species. Thus, the Tabanidæ were a prominent and uncomfortable component of the fauna but all the specimens collected are referable to a single species, *Chrysozona lunulata* (Macquart), and the same appeared to be true for a number of other families including Tetrigidæ and Celyphidæ. This cannot be regarded as a general rule, however, since other groups had much broader representation; the small but prominent family of the Cicindelidæ contained at least six species with two other possible species or sub-species.

In the cultivated areas, the specific composition of the fauna appeared to be considerably reduced with the possible exception of the rice growing areas. This impression was to some extent confirmed by the examination of soil and litter samples, although it must be reiterated that this study is incomplete both from the methods of extraction and the few samples which could be treated.

The general impression is that the arthropodan fauna is numerically abundant but specifically depleted and atypical. Medway (see earlier) has found it necessary to postulate an over-water colonisation to explain a similar phenomenon in the mammals. Although such a hypothesis cannot be rejected for the arthropods, especially since the distance involved is slight and even so is relieved by the presence of the inner islands of the Johore Archipelago, the possibility of the fauna being relict seems more acceptable for the forest forms at any rate. This is rendered the more likely from our knowledge of a land link with the Malayan mainland in recent (Pleistocene) times. Comparison of the fauna with that of acknowledged oceanic types (cf. Gressitt, 1954) is invalidated by the short distance involved in this case. Pulau Jarak in the Straits of Malacca offers a rather better comparison although, due to its small size and greater isolation, such a comparison must not be taken too far. Harrison (1950) has reported an extremely impoverished fauna and although on a recent visit I (Bullock, 1964) found a rather greater arthropodan fauna than is indicated in his paper, it is apparent that few arthropods have reached the island[24]. Even of those which are present, none are particularly abundant with the possible exception of a few spiders. This contrasts strongly with the abundance on Tioman, suggesting that, whereas on Jarak the forms present are casual immigrants, not well suited to conditions but able to survive and maintain themselves, on Tioman they are adapted to their environments. Moreover, few flightless forms, except for spiders and mites, are present on Jarak and the presence of these is readily explained by the wind-dispersion techniques

24. This statement excludes the soil fauna which appeared to be reasonably well represented. This is possibly explained by Tweedie's (1950) suggestion that both flora and fauna were eliminated by deposits of volcanic ash in the late Pleistocene/early post-Pleistocene. It is probable that the soil fauna could survive such conditions which annihilated the unprotected above-soil forms.

of the spiders and the fact that all recorded mites are either ectoparasites or soil-dwellers. On Tioman, all arachnid orders which are known to occur in Malaya were recorded and many myriapods were found including the small and delicate Symphyla and Pauropoda.

It therefore seems preferable to regard this fauna as relict, the atypical composition having arisen since the isolation of the island. Since little is known of the ecological requirements of Malayan arthropods, a detailed analysis is not possible It is however apparent that climatic changes could temporarily destroy an ecological niche throughout the island resulting in the elimination of the forms occupying it. This niche would then be reoccupied by other forms which were unable to compete with the previous occupants but in their absence could utilise it. Thus, in aquatic habitats, drought could have caused the reduction of the freshwater habitats to an extent that predatory forms were considerably reduced and, in the case of Heteroptera, eliminated. The surviving forms have since resurged, presenting the general picture already described.

The presence of distinct sub-species, as has already been shown in the Rhopalocera (Corbett and Pendlebury, 1956; Stubbs, 1961) and in one species of odonate, *Devadatta argyroides tiomanensis* Laidlaw (quoted in Lieftinck, 1954), does not disprove this explanation, since the principles of genetic drift apply as much to a small relict fauna as to an oceanic type.

It is not claimed that there has not been recruitment from the mainland and it is probable that immigration has occurred from time to time, the colonist establishing itself successfully where it was not directly competing with forms already established. This is especially true of the cultivated areas, which have all arisen well after the last inundation of Sundaland. It follows that the animals now found in the cultivated areas have either moved in from the forest or reached the land subsequent to the clearing of the land. Probably one of the most recent colonists is a mollusc, *Achatina fulica* (Giant African Snail) (see Appendix 2) which was recorded on the east side but not on the west.

ARTHROPODA OF PULAU TULAI

P. Tulai was only visited for two short periods during our stay on Tioman, and hence the arthropodan fauna was even less fully collected than on the main island. The general impression of the fauna was of impoverishment as compared with P. Tioman although it included a few forms which were not found on the main island. These included two species of Buprestidæ which were found flying around a tall tree on the highest part of the island. The absence of freshwater on the island precluded the occurrence of aquatic forms except for culicids, some of which are tolerant of brackish conditions whilst others breed in small rain water pools. Odonates, of which several species were taken, had probably crossed from Tioman and several specimens, as well as butterflies, were observed making the crossing. Examination of a small marshy area failed to reveal the presence of odonate nymphs or of any aquatic insect life.

The strand fauna differed little from Tioman. Diptera, chiefly Muscidæ and Sarcophagidæ, were very abundant and were preyed on by asilids and odonates. The flat plain behind the strand was planted with coconut, and due to sea water incursion was dotted with open areas and brackish pools about which grass grew to 2–3 ft. in height. Many Acrididæ were found here as well as several mantids and various spiders including one of the two nephiline argiopids which were recorded from a similar habitat on Tioman, whilst grylloids were plentiful on the ground. The rather lush vegetation about the marshy area was populated by a number of forms including tylid and neriid flies and gallerucid and cassid beetles.

Above the coastal plain, the partially cleared jungle was rather lacking in insects. Butterflies were common in the air, but these, like the odonates, could have quite easily flown across from Tioman. In the leaf litter, termites, ants, and cockroaches were frequent.

On the east coast, a few insects were found on the coral littered beach including small apoids and a small beetle (Cantharidæ?). On rocks well above high-tide mark a few small brackish pools, presumably resulting from a mixture of rain-water and spray, contained Cladocera and culicid larvæ, whilst a number of old wasp nests were found under a rock over-hang, and a machilid was living inside one of these. A large spreading tree which overhung the beach was carrying a heavy infestation of cercopid nymphs which caused a constant rain of watery fluid. According to Wyatt-Smith (quoted in *Malay. Nat. J.*, 1958, 4 (1) : 95) this is an unusual phenomenon; unfortunately no specimen of the tree was taken for identification.

Insects not recorded on P. Tulai although apparently suitable habitats existed included cicadas, cicindelids, curculionids, cerambycids, diopsids, celyphids, tettigonids and panorpids. Although a longer stay might have revealed some of these, it is certain that some at least were not present. These absences appear to be explicable in one of two ways. The clearing of land and subsequent planting of coconut may have so changed the ecology, especially in the early years, that these insects were wiped out and have failed to recolonise the land; or the island might have been completely submerged since the last disappearance of the Sunda shelf. This latter possibility is not untenable since the highest point of the island is only c. 300 ft., but one would anticipate that forms such as cicadas would be capable of recolonising the island from Tioman fairly quickly.

SUMMARY

In a broad survey of the principal terrestrial and freshwater habitats on Pulau Tioman, the principal arthropodan groups are listed and their possible role in the ecology indicated. Ectoparasitic forms are listed in relation to their hosts and identifications of the Siphonaptera are shown in Appendix 1. (Identifications of the Acarina are given in Nadchatram *et al.*, this *Bulletin*, p. 129). The results of a brief study of the soil and litter meiofauna are discussed and the numbers of specimens tabulated. Passing mention is made of the fauna of Pulau Tulai, and the other invertebrates collected, together with additional information on the molluscs obtained by Mr. E. R. Alfred, are shown in Appendix 2.

The origin of the fauna is discussed in relation to the possibilities of its being relict or the result of over-water colonisation. It is suggested that, as far as can be judged, much of the fauna is relict although a certain amount of re-establishment or recruitment, especially in the cultivated areas, has probably occurred since the separation from the mainland.

ACKNOWLEDGEMENTS

I am indebted to all members of the party for their general assistance in the collection of specimens and especially to Mr. K. J. Kuncheria.

Assistance in the preparation of Table 12 was given by Mr. M. Nadchatram. Dr. A. J. Berry kindly identified the mollusc collection and further records of this group were provided by Mr. E. R. Alfred of the Singapore National Museum from material collected by him in 1958 and identified by Mrs. W. S. S. van Benthem-Jutting.

To all these people I am most grateful.

APPENDIX 1

Siphonaptera recorded from Tioman Mammals
(from data supplied by R. Traub, Department of Microbiology,
University of Maryland School of Medicine.)

Stivalius robinsoni. This form was recorded from most of the rodents although the most frequent host was *Tupaia glis tionis.*

Host List: *Tupaia glis; Rattus* sp. *tiomanicus; R. sabanus; R. surifer; Lariscus insignis; Sundasciurus tenuis; Callosciurus notatus; C. nigrovittatus; Iomys horsfieldi;* and domestic cat (*F. domestica*).

Stivalius klossi. Only four specimens were taken from three host species, only single specimens being taken from each host animal.

Host List: *Tupaia glis; Rattus* sp. *tiomanicus;* and *R. surifer.*

Stivalius n.sp. near *S. robinsoni.* Two males were taken from a single specimen of *Lariscus insignis.*

Stivalius sp. Two single females which have not so far been identified to species were recorded from *Tupaia glis* and *Lariscus insignis.*

Ctenocephalus felis felis. Four specimens were taken from a single domestic cat.

Ctenocephalus felis orientis. A single specimen of this sub-species was taken from *Tupaia glis.*

APPENDIX 2

Notes on other Invertebrates recorded from Pulau Tioman

No special attention was paid to free-living invertebrates other than arthropods, but a number of forms were collected and, for the sake of completeness, I have included a few notes on these.

PLATYHELMINTHES: TURBELLARIA: TRICLADIDA:

BIPALIIDAE

Terrestrial planarians were frequently encountered on the forest floor and appeared to be much more abundant than in similar mainland habitats. The specimens collected are referable to two species of the genus *Bipalium, admarginatum* de Beauchamp and *simrothi* Loman, both of which were recorded by de Beauchamp (1933) from material collected on Pulau Tioman. De Beauchamp's locality of Sedagong" on the island is probably synonymous with our "Camp II". A third possible species with a greatly expanded head was also seen but the specimen collected were ruined by a fungal infestation.

ANNELIDA: HIRUDINEA:

HIRUDIDAE

Land Leeches of the genus *Hæmadipsa* were present throughout the forest and were particularly abundant in the vicinity of Camp V.

ANNELIDA: OLIGOCHÆTA:

Juvenile oligochætes were extracted from soil and litter samples and larger specimens were seen from time to time on the soil surface. None of these survived storage in a recognise-able state.

MOLLUSCA: GASTROPODA:

A number of fresh-water and terrestrial gastropods were collected; these have been identified by Dr. A. J. Berry. They are summarised below together with a note of where they were found. Records marked (E.R.A.) refer to specimens collected by Mr. E. R. Alfred in 1958 and identified by Dr. W. S. S. van Benthem Jutting.

ACHATINIDÆ

Achatina fulica Bowdich — several specimens were recorded amongst the coconut plantations at Kg. Juara but were not recorded elsewhere on the island.

BUCCINIDÆ

Anentome sp. — several specimens were taken from rocks in a small stream at 1,000 ft. near Camp II.

CYCLOPHORIDÆ

Cyclophorus perdix-aquila (Sowerby) — specimens were found on the ground in primary forest (also E.R.A.).

Cyclophorus sp.(juveniles) — specimens were taken in both primary forest and regenerating vegetation.

Leptopoma sp. — a number of specimens were taken on the leaves of palms, etc., in primary forest.

HELICARIONIDÆ

Dyakia salangana (Martens) — specimens were taken on the ground in primary forest.
Dyakia ?kintana de Morg. — on land (E.R.A.).
Hemiplecta humphreysiana (Len.) — on land (E.R.A.).
Microparmarion malayanus Collinge — specimens were taken on foliage in primary forest.
?Microcystina sp. (juveniles) — three specimens were taken from litter samples extracted in the Tullgren funnels.

LITTORINIDÆ

Littorina scabra Linn. — a specimen was taken on leaves in the mangrove at Kg. Tekek.

NERITIDÆ

Neritina pulligera Linn. — taken from fresh-water streams from coastal plain to 1,000 ft. (E.R.A.).
N. zigzag Lam. — from brackish water on the coastal plain (E.R.A.).

THIARIDÆ

Melanoides riqueti (Grat.) — in freshwater (E.R.A.).
Thiara scabra (Mull.) — in freshwater (E.R.A.).

ZONITIDÆ

Trochomorpha sp. — a single specimen was taken in a cave, Gua Sinah, at *c.* 2,000 ft.

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10. Parasitic Acarina of the Mammals[25]

By M. NADCHATRAM,

R. DOMROW, *and* C. K. NG

INTRODUCTION

THIS PAPER is an account of parasitic acarines collected from mammals on Pulau Tioman, 18 March to 27 April, 1962. Detailed collection data are not given; the topography of Pulau Tioman, and the ecology of the island mammals, have already been described (Bullock and Medway, this *Bulletin*, p. 1, and Medway, this *Bulletin*, p. 9).

In all, over 160 mammals were searched for parasites under ether anaesthesia. The body and fur were examined for ticks and laelapid mites, and the ear lobes for cheyletid mites. Chiggers (larval trombiculid mites) were sought in the following sites: —ears, muzzle, axillae, belly, and perineum. Only two animals were killed, and their nasal cavities opened and examined for intranasal chiggers after the method of Audy and Nadchatram (1957). All parasites were collected with the aid of a low-power dissecting microscope or hand lens, and all were preserved in 70 per cent alcohol. Specimen host skins were kept for identification. Some mammals were examined for certain parasites, and not for others. Thus in the tables only the actual number of animals examined for the relevant family of acarines is given. The infestations are given in broad terms in Table 1, and in detail in Tables 2–4. The remainder of this contribution consists of a commentary in amplification of these Tables.

Our individual contributions to the paper have been complementary. The mites were collected, and their hosts registered and identified by C. K. N. and B. L. Lim. C. K. N. also identified some of the chiggers. M. N., having identified and recorded the ticks, and much of the other material (including most of the chiggers), collated the data. R. D. identified the remainder of the material and edited the final manuscript. In addition to Mr. B. L. Lim, we are also grateful to the following, who aided in the collection — Mr. J. A. Bullock and Lord Medway (University of Malaya), and Dr. F. L. Dunn, (Institute for Medical Research, Kuala Lumpur). To Mr. Lim Kee Chong of the Institute for Medical Research we are grateful for technical assistance.

MESOSTIGMATA

LAELAPIDAE

Principal references: Strandtmann and Wharton (1958); Drummond and Baker (1960); Keegan et al. (1960); Grokhovskaya and Nguyen Xuan Hoe (1961); Baker et al. (1962); Domrow (1962a); Strandtmann and Mitchell (1963).

A summary of the infestation data is given in Table 2. In all, six genera and eleven species were collected.

Hystrichonyssus turneri Keegan et al.

Numerous specimens from *Atherurus macrourus*. The type series came from the same host on the mainland.

25. This investigation was supported (in part) by a U.S. Public Health Service Research Grant AI-03793-03 (formerly E-3793) from the National Institutes of Allergy and Infectious Diseases, Public Health Service.

TABLE 1

Broad acarine infestation data for mammals, P. Tioman

Host Species	Laelapidae	Spinturnicidae	Argasidae	Ixodidiae	Cheyletidae	Trombiculidae	Listrophoridae
Insectivora:							
Crocidura malavana	..	..	..	*	..	*	..
Hylomys suillus	..	..	..	*	..	*	..
Dermoptera:							
Cynocephalus variegatus	..	..	..	..	..	..	..
Chiroptera:							
Pteropus hypomelanos	*	..	..	..	..	..	..
Cynopterus brachyotis	..	..	..	..	..	..	..
Eonycteris spelaea	..	*	*	..	..	..	..
Rhinolophus	..	..	..	..	..	..	..
Primates:							
Tupaia glis	*	..	..	*	..	*	..
Rodentia:							
Muridae							
Rattus sp. *tiomanicus*	*	..	..	*	..	*	..
Rattus exulans	*	..	..	*	..	*	..
Rattus cremoriventer	*	..	..	*	..	..	..
Rattus sabanus	*	..	..	*	..	*	..
Rattus surifer	*	..	..	*	..	*	*
Sciuridae							
Callosciurus notatus	..	..	..	*	..	*	..
Callosciurus nigrovittatus	..	..	..	*	*	*	..
Sundasciurus tenuis	*	..	..	*	..	*	..
Lariscus insignis	..	..	..	*	*	*	..
Iomys horsfieldi	..	..	..	*	..	..	..
Ratufa bicolor	..	..	..	..	..	..	..
Petaurista petaurista	..	..	..	..	..	..	..
Hystricidae:							
Atherurus macrourus	*	..	..	*	..	..	..
Artiodactyla:							
Tragulus napu	..	..	..	*	..	*	..

Neolaelaps spinosa (Berlese)

A dozen specimens from *Pteropus hypomelanos*. This species is common on *Pteropus* spp. from Ceylon to northern Australia, and is often associated with the nycteribiid flies on these bats (Domrow, 1961).

Echinonyssus nasutus Hirst

Not uncommon on *Tupaia glis;* known from the same host on the mainland and in Vietnam. The type host is *Tupaia picta,* from Sarawak (G. O. Evans, *in litt.*). The single specimens from *Rattus exulans* and *R. surifer* may be regarded as strays or even bench contaminants.

Haemolaelaps gallinarii Grokhovskaya and Nguyen Xuan Hoe

Numerous specimens from one *Sundasciurus tenuis*. This species was originally described from Vietnam and has since been redescribed as *H. audyi* by Baker et al. (1962) from *S. tenuis* from Malaya, and a variety of other hosts, principally squirrels, from Sarawak, Sabah, Palawan and elsewhere in the Philippines.

Laelaps nuttalli Hirst

Collected on *Rattus* sp. *tiomanicus, R. exulans* and *R. sabanus*. This species is virtually cosmopolitan, and has been found on many rats, including *Rattus rattus* and *R. norvegicus*.

Laelaps flagellifer Domrow

Common on *Rattus surifer*. This species was described from *R. rajah* on the mainland, but relationships within the *rajah-surifer* complex are unsettled (but see Hill, 1960).

Laelaps echidninus Berlese

One specimen from *Rattus* sp. *tiomanicus*. This species is virtually cosmopolitan (but see Domrow, 1962c) and found on many rats, including *Rattus rattus* and *R. norvegicus*.

Laelaps spp.

Three further species of this genus were taken on P. Tioman. One, from *Rattus cremoriventer,* is either *L. turkestanicus* Lange or *L. hongaiensis* Grokhovskaya and Nguyen Xuan Hoe, if these species are distinct. The other two, one of which is very close to *L. sanguisugus* Vitzthum, were both common on *R. surifer,* and also recorded once on *R. sabanus*.

Longolaelaps whartoni Drummond and Baker

Common on *Rattus surifer;* described from *R. rajah* on the mainland.

SPINTURNICIDAE

Principle reference: Rudnick (1960).

Meristaspis sp.

Eight specimens from three of four *Eonycteris spelaea* examined.

Ancystropus sp.

Nineteen specimens from three of four *Eonycteris spelaea* examined.

TABLE 2

Mesostigmata infestation data for mammals, P. Tioman

(The first number indicates the number of animals parasitised, the second the number of parasites found)

Host Species	animals examined	*Hystrichonyssus turneri*	*Neolaelaps spinosa*	*Echinonyssus rasutus*	*Haemolaelaps gallinarii*	*Lealaps nuttalli*	*Lealaps flagellifer*	*Laelaps echidninus*	*Laelaps* sp.	*Laelaps* sp.	*Laelaps* sp.	*Longolaelaps whartoni*	*Meristaspis* sp.	*Ancystropus* sp.
Pteropus hypomelanos ..	3	..	1/12	..	..	..	..	..	..	..	..	..	..	..
Eonycteris spelaea ..	5	..	..	..	..	..	..	..	..	..	..	..	3/8	3/19
Tupaia glis	26	..	..	3/4	..	..	..	..	..	..	..	..	..	..
Rattus sp. *tiomanicus* ..	14	..	..	..	..	3/9	..	1/1	..	..	..	..	..	..
Rattus exulans	2	..	..	1/1	..	2/33	..	..	..	..	..	..	..	..
Rattus cremoriventer ..	1	..	..	..	..	..	..	..	1/5	..	..	..	..	..
Rattus sabanus	2	..	..	..	..	1/25	..	..	..	1/13	1/4	..	..	..
Rattus surifer	17	..	..	1/1	..	..	6/109	..	..	13/252	12/109	7/217	..	..
Sundasciurus tenuis ..	2	..	..	..	1/120	..	..	..	..	..	..	..	..	..
Atherurus macrourus ..	2	2/32	..	..	..	..	..	..	..	..	..	..	..	..

METASTIGMATA

Principal references: Kohls (1957); Audy *et al.* (1960); Anastos (1950).

Two families of ticks, represented by four genera and six species, were taken. A summary of the infestation data is given in Table 3. The identification of Malayan ticks in their immature stages is often impossible at present, but wherever possible, the immature stages collected have been compared with specimens obtained during the rearing of known species in the laboratory.

ARGASIDAE

Ornithodoros sp.

Twenty larvae on two *Eonycteris spelaea*. These are probably *O. batuensis* Hirst, the only species known from the mainland. It was originally described from Batu Caves, and has since been recorded from a variety of bats, both Microchiroptera and Megachiroptera, including *E. spelaea*.

IXODIDAE

Ixodes granulatus Supino

Collected on twelve host species. It is a common tick of rodents on the mainland of Malaya, and is the only species known to parasitise rats, squirrels and shrews in all its active stages — larva, nymph and adult. *I. granulatus* is medically significant, because Russian spring-summer encephalitis virus has frequently been isolated from it.

Haemaphysalis atheruri Hoogstraal et al.

This species was taken on three occasions on *Tragulus napu*, and is known from *T. javanicus* on the mainland. One nymph, probably belonging to this species, was taken on *Tupaia glis*. This tick, in small numbers, seems to be host-specific for *Tragulus* in the adult stage. The larvae and nymphs have been taken from rodents.

Haemaphysalis atheruri Hoogstraal et al.

Both specimens of the brush-tailed porcupine, *Atherurus macrourus*, examined were infested with this species. It is the only known host on the mainland.

Haemaphysalis sp.

At least one other species is represented in the collection by immature stages only, collected from *Rattus* sp. *tiomanicus* and *R. sabanus*, but these cannot yet be determined. Forest rats are major hosts of immature *Haemaphysalis* ticks in Malaya.

Amblyomma helvolum Koch

One female specimen on a dead log near the beach, and one nymph on *Rattus sabanus*. In addition, three *R.* sp. *tiomanicus* bore a total of four larvae which appear close to *A. helvolum*, although we hesitate to confirm this diagnosis at present. The natural hosts of *A. helvolum* in all its active stages are typically snakes and lizards, the water monitor (*Varanus salvator*) being one of the common hosts. On several occasions, *A. helvolum* has been found crawling on, but not attached to, man.

TABLE 3

Tick infestation data for mammals, P. Tioman
(Records with asterisks are based on tentative diagnoses)
N=nymph, L=larva

Host Species	animals examined	*Ornithodoros* sp.	*Ixodes granulatus*	*Haemaphysalis traguli*	*Haemaphysalis atheruri*	*Haemaphysalis* sp.	*Amblyomma helvolum*
Crocidura malayana	3	..	3/11N, 5L	..	..	..	..
Hylomys suillus	1	..	1/2L	..	..	..	..
Eonycteris spelaea	5	2/20L	..	..	..	..	..
Tupaia glis	35	..	1/1♀	1/N*	..	..	..
Rattus sp. *tiomanicus*	55	..	7/3♀, 6N, 16L	..	..	1/1N	3/4L*
Rattus exulans	6	..	2/1♂, 2♀, 1N	..	..	..	..
Rattus cremoriventer	4	..	2/1♂, 6♀	..	..	..	..
Rattus sabanus	8	..	..	..	..	2/1N, 8L	1/1N
Rattus surifer	17	..	1/6♀	..	..	..	..
Callosciurus notatus	9	..	1/1♀	..	..	..	..
Callosciurus nigrovittatus	5	..	2/2♀	..	..	..	..
Sundasciurus tenuis	4	..	1/2♀	..	..	..	..
Lariscus insignis	5	..	1/1♂, 1♀	..	..	..	..
Iomys horsfieldi	4	..	1/1♀	..	..	..	..
Atherurus macrourus	2	..	..	..	2/12♂, 2♀, 36N, 7L	..	..
Tragulus napu	4	..	..	3/3♂, 1♀, 1N	..	..	..

PROSTIGMATA

CHEYLETIDAE

Principal reference: Baker (1949).

Cheyletus sp.

Seven females from one *Callosciurus nigrovittatus*.

Chelonotus selenirhynchus Berlese

Eighteen females from one *Lariscus insignis*. This aberrant and monotypic genus is common on many squirrels in the Malaysian subregion (Domrow, 1960).

TROMBICULIDAE

Principle references: Womersley (1952); Audy (1956); Audy and Nadchatram (1957); Traub (1960); Domrow (1962b); Nadchatram and Domrow (1964).

A total of nine genera and 21 species of chiggers were collected from 77 of 114 animals examined, and a summary of the infestation data is given in Table 4. By any standards this is a rich collection, considering approximately 140 species are known from Malaysia as a whole, where most of them are found in primary rain-forest. Audy (1956) and Domrow (1962c) have noted that chiggers show little or no host-specificity, but rather a varying degree of habitat-specificity. Audy also suggests that habitat-specificity may give the appearance of host-specificity. The highest number of species of chiggers found on a single host specimen in Malaya (*Rattus bowersi*) is eighteen.

Leptotrombidium deliense was the most common chigger found on *Rattus* sp. *tiomanicus*, which has a very wide ecological range (see Medway on Mammals, earlier). The occurrence of this mite even on rats trapped in houses is unusual, as the common house rat on the mainland (*Rattus r. diardi*) is free of *L. deliense* although commonly infested with *Ascoschoengastia indica*.

The following animals (numbers examined in parenthesis) were found to harbour no chiggers — *Cynocephalus variegatus* (2), *Iomys horsfieldi* (4), *Petaurista petaurista* (2), *Ratufa bicolor* (1), *Atherurus macrourus* (2), *Rattus cremoriventer* (1), and all the bats, comprising thirteen specimens of four species.

Leptotrombidium deliense (Walch)

Collected from ten of the twelve host species examined, and by far the commonest chigger on the island. *Tupaia glis*, *Rattus* sp. *tiomanicus*, *Rattus sabanus*, *Lariscus insignis* and *Tragulus napu* were its major hosts. Its habitat could therefore range from cultivation, *belukar* and forest fringe, to deep primary rain-forest. It is an established vector of scrub typhus in the Asiatic-Pacific region.

Leptotrombidium langati (Audy and Womersley)

Collected from *Hylomys suillus*, *Tupaia glis*, *Callosciurus notatus*, and *Lariscus insignis*. The occurrence of this species in primary rain-forest on P. Tioman substantiates its authors' claim that it is a very deep forest chigger. On the mainland, it is primarily a parasite of forest rats (especially *Rattus mulleri* and *Rattus bowersi*), tree shrews, ground squirrels, and sometimes tree squirrels, Morphologically, it is closely related to *L. deliense*.

Leptotrombidium bodense (Gunther)

Collected from *Lariscus insignis* and *Tragulus napu*. An uncommon species, easily mistaken for *L. deliense*. Mouse-deer (*Tragulus* spp.), particularly, and squirrels appear to be its major hosts.

Leptotrombidium arenicola Traub

Found on *Tupaia glis, Rattus* sp. *tiomanicus* and *Rattus exulans*. The former is a new host record. One infested *T. glis* was trapped in neglected land between a coconut plantation and a vegetable garden at sea level, and the other in a rice-field 100–150 ft. above sea level. The natural habitat of *L. arenicola* is of epidemiological interest, as this species is a suspected vector of scrub typhus in Malaya (I.M.R. Annual Report, 1960). This species seems to be restricted to open, sandy, coastal areas, and was originally recorded from several islands. A more recent record is from *Rattus* sp. *jalorensis* on Pulau Langkawi. It is again a species closely related to *L. deliense*.

Leptotrombidium muridia (Womersley)

Only one specimen taken, on *Lariscus insignis*. This rare species was described from a single specimen from Malaya, and has since been collected in small numbers on forest rats.

Leptotrombidium sp.

Again, a single specimen taken on *Lariscus insignis*, mixed with other species of *Leptotrombidium*. It is possibly a new species near *L. keukenschrijveri* (Walch).

Siseca rara (Walch)

Six specimens obtained from three *Tupaia glis*. On the mainland, this species has been collected from insectivores, snakes, skinks (*Mabuia multifasciata*), and rodents. A closely related species, *S. subrara* Audy, infests pill-millipedes (*Sphaeropaeus globus-magicus*). Very few trombiculids indeed parasitise hosts other than vertebrates.

Eutrombicula wichmanni (Oudemans)

Eighteen specimens collected from two *Tupaia glis*. This wide-spread species has a wide range of hosts, including reptiles, birds and mammals. A scrub-itch chigger, it causes severe irritation to man, and is well known to Malay village folk by the name of *tungau*.

Ascoschoengastia indica (Hirst)

Found on one of three *Callosciurus notatus* infested with chiggers. This is the commonest chigger on house rats on the mainland. It also occurs in oil palm estates on *Rattus* sp. *jalorensis*, together with *Leptotrombidium deliense*, and all active stages of its life history (larva, nymph and adult) have been recovered from the nests of *Rattus* sp. *jalorensis* in oil palms. Other species of this genus are also known to breed in the nests of their hosts.

Ascoschoengastia audyi (Womersley)

Quite common on *Callosciurus notatus* and *C. nigrovittatus;* the pattern of infestation is similar to that on the mainland.

Ascoshoengastia roluis (Traub and Audy)

A few specimens of this uncommon species on one *Callosciurus tenuis*. It was originally described from Borneo.

Ascoshoengastia calcar Nadchatram and Domrow

This species, like the preceding three, belongs to the subgenus *Laurentella* Audy. Eight specimens were recovered from the two *Rattus surifer* examined for nasal mites. It has been taken in relatively large numbers in the nasal cavities of a variety of forest rats, mixed with species of *Doloisia*, see below.

Susa labuanensis (Womersley)

One specimen taken on *Rattus sabanus*. This rare species has not been recorded since the type series from Labuan, Borneo. Very little is known of the biology of this genus (Audy and Nadchatram, 1960).

Walchiella impar (Gunther)

Collected from *Rattus* sp. *tiomanicus*. This species is usually found mixed with the next species, *W. oudemansi*, to which it is closely related. It is relatively common on the mainland.

Walchiella oudemansi (Walch)

Collected from *Rattus* sp. *tiomanicus*, *R. sabanus* and *Lariscus insignis*. This is a common species on a variety of rodents and some insectivores in scrub, and secondary and primary rain-forest in Malaya.

Helenicula mutabilis (Gater)

Several specimens taken from *Rattus sabanus*. This is a fairly common species on a variety of rodents in lalang, scrub and secondary rain-forest in Malaya, where it is markedly seasonal in occurrence.

Doloisia browningi (Audy and Nadchatram)

Two *Rattus surifer* were examined for nasal mites, and yielded nineteen specimens. The larvae of this, and the following three species (as well as *Ascoschoengastia calcar*), live exclusively in the intranasal cavities of ground-dwelling forest rats. Their preferred site of attachment is to the walls of the chambers lateral to the nasoturbinal bones. The authors give a summary of infestation data of the Malayan species of the genus. Over 20 species in all have been described. Both rats examined carried larvae of all four species of *Doloisia* as well as *Ascoschoengastia calcar*.

Doloisia brachypus (Audy and Nadchatram)

Nineteen specimens of this species were collected from both the *Rattus surifer*. This is the commonest intranasal chigger on the mainland.

Doloisia intermedia (Audy and Nadchatram)

Twenty-four specimens of this fairly common species were taken on both the *Rattus surifer*.

Doloisia domrowi (Audy and Nadchatram)

Only three specimens of this common species were collected from both *Rattus surifer*.

Gahrliepia fletcheri Gater

Recorded from *Rattus* sp. *tiomanicus* and *R. sabanus*. This is the only member of the subfamily Gahrliepiinae to be taken on P. Tioman, although over 25 species are known from Malaya. As many of the animals in the present survey were not examined completely, the group may be more common than our records indicate, as members of this subfamily are minute, and usually attach singly or in very small clusters. On the mainland, it is a common species in primary and secondary rain-forest. The type host and locality are the house rats, *Rattus r. diardi*, Kuala Lumpur, but this rat has not again yielded this species during intensive post-war studies.

TABLE 4

Chigger infestation data for mammals, P. Tioman

As several hundred, or even thousand, specimens of some chiggers were present, only their relative abundance is indicated here. The common species were sorted under a dissecting binocular microscope. Hosts marked with a single + were occasionally, those with two commonly, and those with three heavily, infested with the chigger in question.

Host Species	exam. infest.	*Leptotrombidium deliense*	*Leptotrombidium langati*	*Leptotrombidium bodense*	*Leptotrombidium arenicola*	*Leptotrombidium murtida*	*Leptotrombidium* sp.	*Sisecca rara*	*Eutrombicula wichmanni*	*Ascoschoengastia indica*	*Ascoschoengastia audyi*	*Ascoschoengastia rotuis*	*Ascoschoengastia calcar*	*Susa labuanesis*	*Walchiella impar*	*Walchiella oudemansi*	*Heteniola mutabilis*	*Dolotsia browningi*	*Dolotsia brachypus*	*Dolotsia intermedia*	*Dolotsia domrowi*	*Gahrliepia fletcheri*
Crocidura malayana ..	2/1	+																				
Hylomys suillus ..	1/1	+	+																			
Tupaia glis ..	34/25	+	+		+			+	+						+	+						+
Rattus sp. *tiomanicus* ..	27/23	+	+		+											+						+
Rattus exulans ..	5/2																					
Rattus sabanus ..	10/7	+												+		+	+				+	+
Rattus surifer ..	11(2)/2*												+					+			+	
Callosciurus notatus ..	7/3	+	+							+	+											
C. nigrovittatus ..	5/4	+									+											
Sundasciurus tenuis ..	4/3	+										+										
Lariscus insignis ..	5/4	+	+	+		+										+						
Tragulus napu ..	2/2	+		+			+															

*In all, eleven specimens were examined for ear and body chiggers with negative results. Two were examined for internasal chiggers, and both were infested.

ASTIGMATA

LISTROPHORIDAE

Principal reference: Domrow (1958).

Listrophoroides sp.

Ten specimens from one *Rattus surifer*.

DISCUSSION

The mite material described above is typical of the Malayan mainland, with few exceptions. It is noteworthy that *Dermacentor auratus* Supino and *Amblyomma testudinarium* Koch, common parasites in their immature stages of a wide range of small mammals, were absent in the island collection. This may be correlated with the absence on the island of wild pigs which are the common hosts of the adult ticks. The larvae of the latter species often attack man, their bites causing severe irritation and skin reaction which persist for several weeks or months.

A total of nine genera and 21 species of chiggers were collected on Pulau Tioman. In terms of species the chiggers were the most abundant parasites recorded; all except one species (*Susa labuanensis*) have been recorded on the mainland. The same, in general, is the case with the species of the other six families. Six species of *Leptotrombidium* were taken on the island, five of them infesting the ground squirrel, *Lariscus insignis*. The genus *Leptotrombidium* is of particular interest because some of its members are established vectors of scrub typhus (tsutsugamushi disease) in the Orient and the Pacific. The absence of *L. akamushi*, one of the best known vectors of scrub typhus, is noteworthy. Nor have previous collections from other islands off the Malayan mainland (Pulau Jarak, P. Berhala, P. Langkawi, and the Sembilan islands — including P. Rumbia and P. Pankor), yielded this species. On mainland Malaya, *L. akamushi* is confined to scrub and lalang (*Imperata cylindrica*) wasteland[26], and this would suggest that *L. akamushi* is an introduced species, while *L. deliense* is probably native to Malaya.

The absence of *Ascoschoengastia indica* on *Rattus* sp. *tiomanicus*, which is found in houses and coconut plantation, among other ecological habitats, is also of interest. This species is the commonest chigger on the house rat (*Rattus r. diardi*) on the mainland. Also, all stages of *A. indica* have been found in the nests of *Rattus* sp. *jalorensis* in oil palm.

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11. Notes on the Endoparasites

By Frederick L. Dunn

INTRODUCTION

There do not appear to be any published records for the endoparasitic fauna of Pulau Tioman, with the exception of several reports dealing with human malaria (Dowling and Hughes, 1959; Warren, this *Bulletin*, p. 150). The present paper is an attempt to bring together the available unpublished data on this subject, including a few records by other workers and the preliminary results of a survey of small mammals collected on the island in April 1962.

In the list which follows, the data on protozoa have been brought together primarily from the records of others. The sources of these data will be indicated in the discussions of individual species. All records for helminths and all but one for *Porocephalus* have come from the 1962 survey of small mammals. These animals, and the crude results of the survey, are listed in Table 1. It will be seen that 53 animals of seven species were dissected, and that blood films (taken at 10 a.m.) were also examined from 53 animals. Every blood examination was negative for both haematozoa and microfilariae. Blood films were taken from forest rats, *Rattus sabanus*, and tree shrews, *Tupaia glis*, at 11 p.m. as well as at 10 a.m. to increase the chances of detecting periodic microfilariae. Dissections, moderately thorough for all animals, included examination of the subcutaneous and intermuscular tissues, body cavities, organs, and intestines. Helminths, when collected, were preserved in formalin or glycerine-alcohol.

Table 1

Endoparasites recovered from Tioman mammals (April, 1962).

Hosts	Number Dissected	Number with: Nematodes	Cestodes	Trematodes	Pentastomids	Blood films examined	Number free of blood parasites & helminths
Tupaia glis ...	13	9	—	—	—	13	4
Callosciurus notatus ...	1	—	—	1	—	1	—
Rattus exulans ...	2	—	1	—	—	1	1
R. cremoriventer ...	1	1	1	—	—	1	—
R. surifer ...	8	6	1	1	1	6	—
R. sabanus ...	3	3	1	—	—	3	—
R. sp. *tiomanicus* ...	25	12	11	2	1	28	9
	53	31	15	4	2	53	14

CHECKLIST

The list below includes all known endoparasites of man and animals on Pulau Tioman. Numbers in brackets after the hosts of helminths and *Porocephalus* refer to the number of animals found infected in the small mammal survey. The classification of the Protozoa follows Kudo (1954) while Yamaguti (1958, 1959, 1961) is followed in the classification of the Platyhelminthes and Aschelminthes.

Phylum PROTOZOA (blood parasites only)

Class MASTIGOPHORA

Protomonadina: Trypanosomatidae

Trypanosoma sp. (probably *T. ingens*)	*Tragulus napu*

Class Sporozoa

Haemosporidia: Plasmodiidae

Plasmodium vivax (Grassi and Feletti, 1890) ...	man
Plasmodium malariae (Laveran, 1881) ...	man
Plasmodium falciparum (Welch, 1897) ...	man
Plasmodium inui Halberstadter and von Prowazek, 1907	*Macaca fascicularis*
Plasmodium knowlesi Sinton and Mulligan, 1932	*Macaca fascicularis*
Plasmodium sp.	*Cynocephalus variegatus*
Plasmodium traguli Garnham and Edeson, 1962 ...	*Tragulus napu*

Haemosporidia: Haemoproteidae

Hepatocystis sp. (presumably *H. semnopitheci*) ...	*Macaca fascicularis*
Hepatocystis sp. (probably *H. vassali*) ...	*Sundasciurus tenuis*

Phylum PLATYHELMINTHES

Class CESTODA

Cyclophyllidea

Anoplocephalidae: anoplocephalid species ...	*Rattus sabanus* (1); *Rattus* sp. *tiomanicus* (1) location: small intestine

Davaineidae

Raillietina sp.	*Rattus* sp. *tiomanicus* (7) location: intestines

Dilepididae

Species in Dipylidiinae	*Rattus cremoriventer* (1) location: small intestine

Hymenolepididae

Hymenolepis diminuta (Rud., 1819) ..	*Rattus* sp. *tiomanicus* (3) location: intestines
Rodentolepis sp.	*Rattus* sp. *tiomanicus* (3) *Rattus surifer* (1) location: intestines

Class TREMATODA

Digenea: Dicrocoeliidae

Leipertrema sp.	*Callosciurus notatus* (1) location: small intestine
Zonorchis sp.	*Rattus* sp. *tiomanicus* (2) *Rattus surifer* (1) location: small intestines

Phylum ASCHELMINTHES

Class NEMATODA

Rhabdiasidea: Strongyloididae

Strongyloides ratti Sandground, 1925 ... *Rattus surifer* (1); *Tupaia glis* (2) location: small intestine larvae in faeces

Strongylidea: Strongylidae

Globocephalus sp. ... ... *Rattus sabanus* (2) location: small intestines

Strongylidea: Ancylostomatidae

Cyclodontostomum purvisi Adams, 1933 ... *Rattus surifer* (2) location: large and small intestines

Strongylidea: Trichostrongylidae

Nippostrongylus brasiliensis (Travassos, 1914) ... *Rattus sabanus* (2); *Rattus* sp. *tiomanicus* (6) location: small intestines primarily; also large intestine

trichostrongylid species ... ... *Rattus surifer* (1) location: small intestine

species (Trichostrongylinae) ... ... *Rattus surifer* (1); *Tupaia glis* (1) location: small intestine

species (Trichostrongylinae) ... ... *Rattus* sp. *tiomanicus* (4) location: small and large intestines

species (Strongylacanthinae) ... ... *Tupaia glis* (2) location: small intestines

Strongylidea: Protostrongylidae

Angiostrongylus cantonenisis (Chen, 1935) ... *Rattus* sp. *tiomanicus* (1) location: lung

Oxyuridea: Oxyuridae

Syphacia muris (Yamaguti, 1935) ... ... *Rattus* sp. *tiomanicus* (2); *Rattus surifer* (1); *Rattus cremoriventer* (1) location: intestines (primarily large)

Spiruridea: Gnathostomatidae

Gnathostoma sp. ... ... *Rattus* sp. *tiomanicus* (1); *Rattus surifer* (1) location: stomach wall

Spiruridea: Physalopteridae

Physaloptera sp. ... ... *Rattus* sp. *tiomanicus* (3) location: stomach; intestines

Filariidea

filariid species ... ... *Rattus surifer* (3); *Rattus sabanus* (1); *Tupaia glis* (7); *Rattus* sp. *tiomanicus* (3) location: subcutaneously on limbs, back, head, base of tail

microfilaria sp. ... ... *Rattus* sp. *tiomanicus*

microfilaria (*Setaria* sp.) ... ... *Tragulus napu*

microfilaria (*Dirofilaria* sp.?) ... ... *Macaca fascicularis*

microfilaria sp. ... ... *Macaca fascicularis*

Phylum ARTHROPODA

Class PENTASTOMIDA

Porocephalida: Porocephalidae

Porocephalus moniliformis (Diesing, 1834) ... *Macaca fascicularis* (1); *Rattus surifer* (1); *Rattus* sp. *tiomanicus* (1); location: (of nymphs) liver: intestinal wall

ANNOTATIONS

Trypanosoma sp. (probably *T. ingens*)

This trypanosome has been recorded recently from mouse-deer, *Tragulus javanicus*. collected in Pahang (Annual Report of the Institute for Medical Research for 1961). A member of the *lewisi* group, the trypanosome has been recorded previously from African antelope. The presence of this trypanosome in Tioman mouse-deer (*T. napu*) is reported by Dr. A.B.G. Laing (personal communication).

Plasmodium inui and **P. knowlesi**

These primate malaria parasites are common in Malayan macaque monkeys. Drs. D. E. Eyles and M. Warren have identified these plasmodia, as well as a *Hepatocystis* sp. (presumably *Hepatocystis semnopitheci*), in blood films from a number of *Macaca fascicularis laeta* collected on Tioman in September 1961 and April, 1962 (Warren, this *Bulletin*, p. 156).

Plasmodium spp.

A malaria parasite was discovered in a single blood film from a flying lemur, *C. variegatus*, collected on Tioman in September 1961 by Drs. Eyles and Laing. Subsequently we have found a *Plasmodium*, presumably the same parasite, in a flying lemur captured at Bukit Lagong near Kuala Lumpur. It has been possible to study the parasite, which belongs to a new species, in some detail; a description will be published elsewhere.

A *Plasmodium* species has also been found in blood films from Tioman mouse-deer, *T. napu* (A. A. Sandosham, personal communication). New species of both *Hepatocystis* and *Plasmodium* have recently been discovered in mouse-deer (*T. javanicus*) collected in Pahang and Selangor. These species have been described as *H. fieldi* and *P. traguli* by Garnham and Edeson (1962). It is probable that the parasite in Tioman mouse-deer is also *P. traguli*. A *Hepatocystis* sp., presumably *H. vassali*, has also been noted by Dr. M. Laird in a blood film from a squirrel, *Sundasciurus tenuis* collected on the island in April 1962 (personal communication).

Hymenolepis diminuta and **Raillietina** sp.

The former cestode, and possibly the latter as well, may be of at least potential medical importance on Pulau Tioman. *H. diminuta* is cosmopolitan in rodents and not infrequently infects man; several species of *Raillietina* normally parasitic in other mammals, including rats, have also occasionally been recorded from man.

Leipertrema sp.

This dicrocoeliid trematode of *Callosciurus notatus* closely resembles a new species of *Leipertrema* from *C. notatus* collected near Kuala Lumpur and described by Rohde (1963). It probably belongs to the same species, but preliminary comparison of measurements and characters of a series of Tioman specimens and specimens from Bukit Lanjan near Kuala Lumpur reveals certain differences: the testes of the Tioman form are generally much smaller; the maximum body diameter is usually posterior to mid-body in the Tioman form and anterior to mid-body in the other; the eggs of the Tioman form are smaller and consistently shorter; and the vitellaria are less compact in the Tioman form. There is some overlap in the measurements: it is probable that we are dealing with morphologically divergent populations of the same species (sub-species, in effect). This divergence in form—of parasites in the same host species—is of interest because of the island isolation

of one of the host populations. The morphological differences in the island trematodes suggests that their hosts have been resident on the island, and cut off from mainland *C. notatus,* for a considerable period of time, perhaps longer than some of the ground-dwelling rats.

Zonorchis sp.

At least one undescribed species of *Zonorchis* occurs in rodents of the Kuala Lumpur area (Rohde, personal communication). The Tioman form is very similar to the mainland species and may be conspecific with it.

Cyclodontostomum purvisi

This strongylid nematode does not appear to have been recorded from any host since Adams (1933) first described it from Malayan rats. The worms found in *R. surifer* do not differ in any important respects from the original description.

Species in the Family Trichostrongylidae

In addition to the well-known, cosmopolitan rodent parasite, *Nippostrongylus brasiliensis,* four other trichostrongylid species were recognised in rats and tree shrews. Two of the four, represented only by female worms, cannot be assigned to genera. A third species, found only in *R.* sp. *tiomanicus,* is well represented by male and female worms which can be assigned to the Trichostrongylinae but not to any of the known genera within this sub-family. Another species, found only in *Tupaia glis,* is referrable to the Strongylacanthinae and also appears to belong to a new genus, somewhat resembling *Molinostrongylus.*

Angiostrongylus cantonensis

This nematode has recently been shown to be of some importance to human health in that the larvae, once established in the human host, may in the course of their migrations, initiate a disease now known as eosinophilic meningitis (Horio and Alicata, 1961; Rosen et al, 1962). Cases of this disease have so far been recognized only in Hawaii and Tahiti. *A. cantonensis* is known from the mainland of Malaya as well as from Tioman. Schacher and Cheong (1960) recorded the worm from *R. r. diardi* and *R. exulans* collected in Singapore and Kuala Lumpur.

Syphacia muris

This oxyurid nematode may also be of some potential importance to human health. A closely related species, *S. obvelata* (Rud., 1802), cosmopolitan in rats and mice, has been reported several times from children in the Philippines and the United States.

Gnathostoma sp.

Adult gnathostomes were collected from the stomachs of two rats trapped above 3000 ft. on the upper slopes of Gunong Kajang and near Camp V. It is surprising that two of the six rats examined for helminths from the highest parts of the island should have carried these worms while none of the animals trapped at lower altitudes (all other surveyed animals were trapped between sea level and approximately 1100 ft.) were so infected. The worms appear to belong to an undescribed species somewhat resembling *G. doloresi.*

Representatives of the Order Filariidea

In the course of the dissections worms of only a single filariid species were found. Unfortunately no male or mature female specimens were recovered so the material cannot be assigned to genus or sub-family. Microfilariae were not detected in blood films taken from 53 Tioman rodents and tree shrews. Dr. M. Laird has,

however, noted microfilariae in a blood film from one *R.* sp. *tiomanicus* collected on the island in April 1962 (personal communication). Also, microfilariae resembling those of *Setaria* were discovered in blood films from four of six mouse-deer (*T. napu*) collected on Tioman in September 1961 by Eyles and Laing (personal communication); and Warren (personal communication) found two species of microfilariae, one apparently a *Dirofilaria,* in blood films from one of eight *Macaca fascicularis* collected in April 1962. One other record for a possible filariid was obtained by the writer in April 1962 in the course of dissections of freshly collected tabanid flies, *Chrysonzona lunulata* (Macquart). In one of 12 dissected flies a single nematode larva, about 1080 microns long and 20 microns in maximum diameter, resembling a larval filarial nematode, was found in the crushed thorax. These flies occurred abundantly in forest, and were readily attracted to man.

Porocephalus moniliformis

Nymphs of this pentastomid worm were found encysted in the liver of a long-tailed macaque dissected by D. E. Eyles during a visit to the island in September 1961. Nymphs were also removed from the liver and intestinal wall of two rats examined in the course of the small mammal survey. The adult tongue worms are commonly found in the air passages of pythons and other snakes. In view of the relatively high prevalence of infections (3 in 54 dissections) *P. moniliformis* must be a rather common parasite of the island's snakes.

DISCUSSION

The host-parasite list for Tioman emphasizes the many gaps in our knowledge of the island's endoparasites. There are, for example, no records for intestinal protozoa or helminths of humans living on the island. Nor are there any records for tissue helminths. It seems unlikely, however, that human filariasis transmission takes place on the island. Microfilariae have apparently not been noted in blood films taken from man in past surveys for malaria, and there is some doubt that common vectors of either periodic or sub-periodic *Brugia malayi* occur on the island (R. H. Wharton, personal communication). The present small mammal survey covers only a few species, and only three of these (*T. glis, R.* sp. *tiomanicus,* and *R. surifer*) in any number. Except for a few records of blood parasites we have no information at all for other Tioman mammals. The bird, reptile, amphibian, and fish parasites are totally unknown.

In spite of the deficiencies noted above it is possible to make a few comparisons with the situation on the Malayan mainland, although here too, except for the endoparasites of man and his domestic animals, the parasites are at present poorly known. The rodents, fortunately for our purposes, have received some attention, permitting direct comparisons with Tioman data.

Rattus rattus diardi, the ecological counterpart on the mainland to *R.* sp. *tiomanicus* in the commensal part of its range (Medway, this *Bulletin,* p. 20), was found to be a host for 9 species of nematodes in Kuala Lumpur and Singapore by Schacher and Cheong (1960). On Tioman *R.* sp. *tiomanicus* is a host for at least 7 species of nematodes. Three of these 7 (*Syphacia muris, Angiostrongylus cantonensis,* and *Nippostrongylus brasiliensis*) have been recorded from *R. r. diardi* elsewhere in Malaya. In addition, *R.* sp. *tiomanicus* harbours at least four species of cestodes, one trematode, and a pentastomid. Thus, in numbers of species of parasitic helminths there is certainly no major difference between the commensal *R. rattus* of the mainland and the principal commensal (and forest) rat of Tioman.

Of the 25 *R.* sp. *tiomanicus* dissected, 9 were entirely free of helminths (within the limits of the dissecting technique). At first glance an infection rate of only 64 per cent might suggest that helminths, while not "depleted" in terms of numbers of species, may be so in terms of infection rates in the Tioman rat. Comparison with the mainland data shows, however, that *R. r. diardi* and related rats of the subgenus *Rattus* are frequently entirely free of helminths (on the basis of dissections performed in the same laboratory as those under consideration here). In the helminth-host records compiled by Sandosham (1957) only 396 (65 per cent) of 605 *R. r. diardi,* and 126 (49 per cent) of 258 *R.* sp. *jalorensis* were found infected with any kind of helminth. Thus commensal and field rats of the *R. rattus* group of Kuala Lumpur had overall helminth infection rates similar to the rate for the single representative of the group on Tioman. In this connection it is interesting to note that the overall helminth infection rate for *R.* (*rattus*) *jarak* (9 of 14 animals with helminths in the Sandosham tabulation) of Jarak Island in the Straits of Malacca was 64 per cent, another figure (again based on a small sample) close to that for *R. r. diardi* of Kuala Lumpur. (For comment on the taxonomy of the *R. rattus* group in relation to Tioman, see Medway and Lim, this *Bulletin,* p. 33).

Tupaia glis from Tioman were found to be hosts for only four species of nematodes and no other helminths. *T. glis* from any one mainland locality, however, do not often serve as hosts for more than five or six species of helminths, including cestodes (unpublished data). The number of species of parasitic helminths and the overall helminth infection rates appear to be roughly the same for Tioman and mainland tree shrews.

Although only eight *R. surifer* were available for dissection, the recovery of 10 species of helminths from this small sample suggests that the helminth fauna of this host species is not particularly 'reduced' on the island.

The helminth evidence, taken by itself, suggests that the commonest ground rodents and the tree shrews were introduced from the Malayan mainland in relatively 'recent' times. The animals carry many helminths commonly found in the same or closely related species on the mainland, with apparently comparable infection rates. Although there are some new helminth forms in this small sample, their presence cannot be taken as evidence for prolonged isolation of their hosts because we do not know whether or not these same new species may occur on the mainland. It seems more likely that they will eventually be found in mainland hosts than that they will not.

Although similarities in the helminth fauna of mainland and Tioman rats and tree shrews predominate, there are a few notable differences. First and most striking is the total absence of acanthocephalans, particularly from the local representative of the *R. rattus* group. Sandosham (1957) records 108 *R. r. diardi* infected with Acanthocephala in a total of 605 dissections. Another notable deficiency in the Tioman helminth fauna is in the rat and tree shrew spirurid nematodes. *Gongylonema, Rictularia,* and *Protospirura* species, common in mainland commensal rats, were not found; nor were species of *Spirura* and *'Subulura'* which are seen in mainland *Tupaia.* Finally, members of the Trichuridea were also missing from the Tioman animals.

In contrast to the missing forms which one might have expected to find, the trichostrongylid nematodes were conspicuously abundant, both in numbers of species and numbers of individuals per infected host. While Schacher and Cheong (1960) recorded only one intestinal trichostrongylid from three species of rats collected in Singapore and around Kuala Lumpur, five species were recorded from three rat species and the tree shrew on Tioman. Clearly the trichostrongylids have

been able to thrive in their Tioman hosts. The prevalence of *Nippostrongylus brasiliensis* infection was very low in the survey of Schacher and Cheong (who referred to this species by its former name, *N. muris*); on Tioman six of 25 *R.* sp. *tiomanicus* and two of three *R. sabanus* carried large numbers of the worms. Some of these observed differences may, of course, reflect differences in collecting technique.

It is worth noting lastly, that the primate, *Tupaia glis*, which has proliferated remarkably on the island, has an endoparasite pattern which largely overlaps with that of *Rattus surifer*, and to a lesser extent with the patterns of the other rats. Three of the four nematodes of *T. glis* were found in *R. surifer;* and *R. surifer* in turn has a helminth pattern which overlaps to a considerable extent with that of *R.* sp. *tiomanicus*. *T. glis*, although a primitive primate and far-removed phylogenetically from the rats, shares with them the physiologic 'ability' to support certain helminths. These helminths, in turn, indicate (serving as "ecological labels'—Audy, 1947) that *T. glis* must to some extent compete for the same foods in the same habitats with *R. surifer* and the other ground rats; this is confirmed by other evidence (Medway, this *Bulletin*, p. 14).

SUMMARY

1. A list of the known endoparasites of man and animals on Pulau Tioman is presented and supplemented by annotations. The protozoa are represented by one species of *Trypanosoma*, six or seven species of *Plasmodium*, and two or three species of *Hepatocystis*. Five cestodes, two trematodes, and 16 nematodes comprise the helminths recorded to date from the island. A single endoparasitic arthropod, *Porocephalus*, completes the list.

2. A series of dissections of small mammals provided most of the helminth records presented herein. Seven of the 23 helminths were identified to species, eight more to genus, and the reminder, for various reasons, only to family or sub-family. At least two new species of trichostrongylid nematodes and one new gnathostome were collected. Some of the other helminths identified only to genus at this time may prove, with further study, to be undescribed forms.

3. The following helminths and endoparasitic arthropods of potential or possible importance to human health were recorded from animals on the island: *Hymenolepis diminuta*, *Raillietina* sp., *Angiostrongylus cantonensis*, *Syphacia muris*, *Gnathostoma* sp., and *Porocephalus moniliformis*.

4. In a concluding section the patterns of helminthic infection of mainland and island rodents and tree shrews are compared and contrasted. It is concluded that the helminth fauna of the ground rodents and tree shrews is not particularly depleted on the island. Overall parasite infection rates, and numbers of parasitic species per host species are roughly comparable for mainland and island *Tupaia glis*, *Rattus surifer*, and rats of the *R. rattus* group. A few striking differences do, however, occur in the patterns of helminthic infection of the mainland and island rodents and tupaias. Trichostrongylid nematodes are conspicuously abundant on the island, both in numbers of species and numbers of individuals; certain spirurid and trichurid nematodes commonly found in the mainland hosts are apparently absent from their island counterparts. Acanthocephala, common in *R. r. diardi* on the mainland, do not seem to be present in island rodents. A simple example, involving *T. glis* and ground rodents, is presented of the use of helminths as 'ecological labels'.

ADDENDUM

Since completion of this paper word has been received of the detection of *Wuchereria bancrofti* microfilariae in two island residents in the course of a malaria survey by the Pahang Health Department in August 1962 (Warren, personal communication). Whether these infections were imported from the mainland or acquired locally is unknown at this time.

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12. Primate Malaria

By McWILSON WARREN

Pulau Tioman has been recognized as a severely malarious area for many years. However, published material on this subject is quite limited and most of the information available must be gleaned from unpublished reports primarily found in the files of the Institute for Medical Research in Kuala Lumpur. The 1949 report of Dr. J. W. Field, at that time Senior Malaria Research Officer of the Institute for Medical Research, contains the most complete medical background available on the island. Briefly the medical history of this island begins in 1924 with the establishment of a dispensary at Kampong Juara on the east coast. There is a verbal report of a "great epidemic" in 1926 which killed many people and caused the east coast of the island to be virtually abandoned. Interestingly enough there is still only one inhabited kampong (village) on this side of the island and the extent of secondary jungle covered former clearings is mute testimony to the fact that human habitation was much greater in this area in the past. The etiology of this epidemic is still unknown but Dr. Field believes that a "virulent outbreak of *falciparum* malaria" cannot be excluded. In 1930, the present dispensary at Kampong Tekek on the west coast of the island was constructed.

Efforts to control malaria were instituted between 1937 and 1942. This consisted of clearing and oiling of the main streams at Kampong Tekek and Kampong Juara. These efforts were apparently unsuccessful. Dr. Field visited Tioman in 1941 and reported that the malaria incidence was higher on the island than he had observed any place else in Malaya.

During the years of World War II a Japanese garrison was quartered on the island but no apparent effort was made to improve the health of the population during this period.

In 1947 the island was visited by Dr. McGarity, the Health Officer of East Pahang, and the dispensary was re-opened. Through the auspicies of the Institute for Medical Research, a program for the massive administration of paludrine to the population of the island was undertaken. Due to commitments of the Institute staff in Selangor and Negri Sembilan, no actual survey was carried out prior to the initiation of this program. However the impression at this time was that there was much general sickness and that the incidence of malaria was high.

In order to evaluate the effect of paludrine administration a survey was conducted on the island in 1948 (Table 1).

TABLE 1

Spleen and parasite rates on Pulau Tioman, April 1948

	Spleen Rates			Parasite Rates		
	No. Exam.	No. Enl.	%	No. Exam.	No. Pos.	%
Children	169	95	56	133	31	23
Adults	231	94	41	231	9	4
Total ...	400	189	47	364	40	11

In this particular survey 25 per cent of the diagnosed cases were *Plasmodium vivax*, 32 per cent were *P. falciparum* and 43 per cent were *P. malariae*. No conclusions were drawn as to the effectiveness of paludrine administration but it was felt at this time that the spleen rate was lower in the children than might have been expected and that the parasite rate was lower than would be indicated by the spleen rate. At this time the Senior Malaria Research Officer in the Institute for Medical Research recommended that paludrine prophylaxis be continued under the supervision of a trained hospital assistant.

Dr. J. W. Field led a survey team to Pulau Tioman in 1949. The report of this effort is currently on file at the Institute for Medical Research in Kuala Lumpur. Unfortunately, the actual amount of malaria on the island at this time is unknown. Dr. Field's group took more than 500 blood smears which were returned to the IMR in Kuala Lumpur for examination. Unfortunately all of these smears were contaminated with a spore-forming bacillus and were difficut to evaluate. Thirty-three specimens could be reported as positive but this cannot be assumed to represent the total positive films taken at the time. It is interesting to note, however, that 12 per cent of the positive films were diagnosed as *P. vivax*, 52 per cent as *P. falciparum* and 36 per cent as *P. malariae*. Recommendations were made at this time for the continued administration of paludrine with a concomitant spraying of houses. Follow-up surveys were to be conducted in 1950. There is no record that such a follow-up was made.

The next recorded effort made to ascertain the status of malaria on Pulau Tioman was done in 1955. Dowling and Hughes (1959) reported the results of an Army investigation on the island (Table 2). The impetus for this visit resulted from the occurrence of several cases of malaria among British personnel who had visited the island. Incidentally this is the only published report available at the present time.

TABLE 2

Spleen and parasite rates on Pulau Tioman, June 1955

Spleen Rates			Parasite Rates		
No. Exam.	No. Enl.	%	No. Exam.	No. Pos.	%
120	93	61	120	70	58

Among the positive cases 69 per cent were *P. vivax*, 23 per cent were *P. falciparum* and 8 per cent *P. malariae*. This survey reported above was performed primarily on children 10 years of age and under. Spleen rates and parasite rates were highest in the group 4 years of age and under. Recommendations were made that one dose of chloroquine be administered to all people on the island and that a prophylactic dose of paludrine be given weekly for six weeks. In addition is was recommended that insecticide fogging, as well as residual house spraying, be undertaken. These recommendations were accepted and, with the cooperation of Army personnel from Singapore, were carried out in September, 1955. Follow-up surveys were conducted in May 1956. The results of the survey are briefly summarized below (Table 3).

TABLE 3

Spleen and Parasites rates on Pulau Tioman, May 1956

Parasite Rates			Spleen Rates		
No. Exam.	No. Enl.	%	No. Exam.	No. Pos.	%
126	22	17	125	3	2.4

As would be expected the efforts instituted by the Royal Army Medical Corps influenced the general status of malaria on this island by a considerable degree. Spleen rates were approximately 70 per cent lower and parasite rates were approximately 95 per cent lower in 1956 than in 1955. However it should be noted that two of the positive cases were *P. falciparum* in infants born during the time when spraying procedures and the massive administration of drugs were undertaken. Since the drug administration was a short-term effort, it may be assumed that neither of these children had been given prophylactic therapy. Unfortunately the presence of two infants in this community demonstrating patent infections with *P. falciparum* one year after this concentrated attack on malaria is also presumptive evidence that effective transmission never really ceased on the island. In addition it should be noted that the follow-up survey was conducted primarily on the school children and this is the group that would have been most prone to take the full drug treatment the previous year. Under these circumstances, the 1956 survey probably does not represent an adequate sample of the total susceptible population living on the island at the time. In other words such a short-term project could not be expected to cause any lasting change in the human malaria pictures on the island, and later figures indicated the expected re-emergence of malaria as a significant disease problem.

Information relative to the status of malaria on the island between 1956 and 1960 has been obtained through the cooperation of the Pahang State Health Department in Kuantan. The dispensary has been functioning and anti-malarial drugs are and have been available to those individuals who requested them. In addition the hospital assistant travels around the island by boat every two weeks with what is called a travelling dispensary. Residual spraying of houses is carried out, but due to the transport problem this can only be accomplished once each year. A blood survey was conducted by the Pahang State Health Department on Pulau Tioman in August, 1960 in which 733 blood films were examined (Table 4).

TABLE 4

Parasite rate on Pulau Tioman, August 1960

No. Examined	No. Positive	% Positive
733	101	14

The species distribution in the positive films was 64 per cent for *P. vivax*, 28 per cent for *P. falciparum* and 9 per cent for *P. malariae*. This survey serves to confirm the species shift that had been reported in 1955 and the transient nature of results obtained against malaria by short-term drug administration and insecticide fogging.

The latest available information on the status of malaria on the island is from a survey conducted in August of 1962 by members of the Malaria Control Section of the Pahang State Health Department. The results of this survey are seen in Table 5.

TABLE 5

Parasite rate on Pulau Tioman, August 1962

No. Examined	No. Positive	% Positive
206	39	19

The species distribution in the positive films was 49 per cent for *P. falciparum*, 28 per cent for *P. vivax*, 8 per cent for *P. malariae*, 8 per cent for mixed infections, and 7 per cent of the positive films were not identified as to species.

The species distribution of malaria on Pulau Tioman has shown some interesting changes since 1948. Four surveys have been carried out and Table 6 shows several interesting developments over this period of 14 years. In 1948 the crude

parasite rate in this population was only 11 per cent and the majority of these were, surprisingly enough, diagnosed as *P. malariae*. A period of seven years elapsed before another malaria survey was conducted on the island and further changes occurred during this interim. There was more than five times as much malaria in the total population as in 1948, with *P. vivax* showing a 13 fold increase; and *P. falciparum* was four times as abundant in 1955 as in 1948. The incidence of *P. malariae* remained virtually unchanged. From these figures certain conclusions can be drawn relative to the anti-malaria activities on the island during this period. As previously noted recommendations for paludrine administration and the residual spraying of houses were made in 1948 but it must be assumed that these measures at best were only sporadicallly carried out between 1948 and 1955.

In 1960 the crude parasite rate on the island had dropped to 14 per cent. This is reflected in drops in the prevalence of all three species. *P. falciparum* was back to essentially the same level as in 1948 while *P. vivax* was still three times as common in 1960 as in 1948, though the incidence of this species had decreased markedly since 1955. Only a little more than one per cent of the population were infected with *P. malariae* in 1960. The 1962 survey showed a disconcerting increase in the amount of sub-tertian malaria on the island. *P. vivax* had continued to decrease and *P. malariae* remained at low level; however, *P. falciparum* was more than twice as prevalent in 1962 as in 1960. At the present time there is no explanation for the recent increase in this species of *Plasmodium* on Pulau Tioman.

The current program for malaria control on the island involves two specific procedures. The houses on the island are sprayed with residual insecticides once each year and prophylactic chloroquine and paludrine is theoretically provided for every individual on the island. However the hospital assistant reported having 1,343 patient visits in both the permanent dispensary at Kampong Tekek and in the travelling dispensary in the first half of 1962. A diagnosis of malaria was made in 123 of these patient visits. Most of these were based on a clinical rather than a parasitological examination; however, the 19 per cent crude parasite rate reported in August, 1962 is based on parasitological examinations.

There is no doubt that there is an intensive level of malaria transmission on the island. The number of *P. falciparum* cases reported in the 1962 survey is alarming and indicates a considerable increase in the amount of this species of malaria on the island since 1960.

In spite of yearly spraying of the houses and the dispensing of large quantities of chloroquine and paludrine the incidence of malaria on the island has remained quite high. At present it would seem that the residual insecticide program is exerting little influence on the malaria picture in this area. One spraying each year, especially when this may be delayed several months due to transport difficulties and always hampered by a number of houses that are locked and cannot be sprayed, is probably not sufficient to break effectively the malaria transmission cycle. The combination of chloroquine prophylaxis and an increase in the amount of sub-tertian malaria is quite interesting. There are two possible explanations for this situation. Either the *P. falciparum* found on the island is resistant to chloroquine or the drug, even though both supplied and dispensed, is not actually taken by the island's inhabitants. Until further information is available it is probably reasonable to assume that the drug is not effectively taken by most of the people.

An incidental finding in the August, 1962 survey that is not related to malaria but has caused much interest was the discovery of two blood films which were positive for *Wuchereria bancrofti*. There have been no previous reports of filariasis from Pulau Tioman. It is not known at present whether these cases are permanent inhabitants or were transient fishermen from the mainland. This problem is currently under investigation.

TABLE 6

Malaria on Pulau Tioman, 1948–1962

Year	No. Exam.	No. Pos.	% Pos.	Species Break-down					
				P. falciparum		*P. vivax*		*P. malariae*	
				No. cases	% Exam.	No. cases	% Exam.	No. cases	% Exam.
April, 1948	364	40	11	13	3.57	10	2.74	17	4.67
June, 1955	120	70	58	16	13.3	48	40.0	6	5.0
August, 1960	733	101	14	28	3.8	64	8.7	9	1.2
August, 1962	206	39	19	19	9.2	11	5.3	3	1.4

STATUS OF MALARIA VECTORS

Data collected prior to World War II have been lost and there is only a verbal record of the *Anopheles* collected during this period. Larval surveys had produced *A. aitkeni, A. barbirostris, A. hyrcanus, A. kochi, A. leucosphyrus, A. maculatus, A. subpictus, A. sundaicus, A. umbrosus, A. vagus* and *A. watsoni*. However, the character of any individual larval survey would vary markedly between dry and rainy seasons. In adult night catches *A. maculatus* and *A. sundaicus* were the predominant mosquitoes. These observations are abstracted from the now recorded verbal records prior to World War II and from the survey conducted by Dr. Field in 1949.

In September 1961, additional data on the anopheline fauna of the island was collected by a team from the Institute for Medical Research. *A. maculatus, A. sundaicus* and *A. barbirostris* predominated in larval collections at this time.

Further larval collections were made in April of 1962 during the period when the team from the University of Malaya was present on Pulau Tioman. Collections along the coastal areas produced numerous *A. maculatus, A. barbirostris* and *A. aitkeni*. Interestingly enough, no *A. sundaicus* larvae were found. Collections made in seepage pools and rock pools deep in the rain forest in the center of the island gave the ubiquitous *A. aitkeni* and the very interesting addition of *A. riparis*.

THE ECOLOGY OF HUMAN MALARIA ON PULAU TIOMAN

With the information currently available a fairly definite understanding of the basic features of the ecology of human malaria on the island can be determined. The human population is currently concentrated in three areas on the island. Kampong Tekek (a complex of several kampongs oriented along a five mile stretch of open beach) on the west coast, Kampong Mokut on the south coast and Kampong Juara on the east coast. In the past the population was probably considerably greater but was still confined to the narrow strips of coastal plain adjacent to the open beach areas. Under the circumstances it can be seen that all of the human inhabitants of the island live in virtually the same environment. This environment consists of a narrow flat strip of sandy soil given over for the most part to coconut plantings. This area is laced with many small tidal streams which create innumerable brackish to fresh water pools which are ideal for breeding of *A. sundaicus, A. bazai* and *A barbirostris*. Even *A. maculatus* has been found in this area. This narrow coastal plain ends abruptly with the beginning of the steep hills which cover most of the island. In this area, usually within a few hundred yards of the kampong houses, man has created an ecological area remarkably well suited to the proliferation of *A. maculatus,* the most effective vector of human malaria in Malaya. The forest on the lower aspects of the hills is cleared for tapioca and dry rice plantings. Such hill clearings provided large seepage areas which are the breeding sites of choice for *A. maculatus*. Since new areas are constantly being cleared, there are always fresh breeding sites available.

Thus we have man residing in the midst of ideal breeding areas for two proven vectors of malaria in Malaya. Unfortunately, an ecology more beautifully attuned to the continued transmission of malaria would be difficult to imagine.

The status of the disease in the human population testifies to this continuous transmission. Virtually all of the children are infected when they are quite small and many die. Spleen rates have been very high in the children under five years of age, with concomitant high parasite rates in this age group. On two occasions following short-term but intensive anti-malaria campaigns the parasite rates have been temporarily reduced to fairly low levels. Generally, as the surviving children grow older a rather high level of immunity develops. Adults will, on

occasion, show patent parasitemias and frequently have enlarged spleens but do not show the usual clinical response to the presence of the parasite. This is the picture seen in other areas where malaria is hyperendemic and long standing. Primarily, morbidity and mortality is confined to the children in the population, with adults being capable of maintaining the parasite but showing little or no clinical response. This has apparently been the malaria picture for many years on the island.

Some control measures have been undertaken. As has been noted, since 1956 residual spraying with BHC (Gammexane) has been carried out, and since 1960 spraying with dieldrin has been attempted. However, this has been done only once each year. Drugs are available on request by the island's inhabitants. However with a crude parasite rate of 19 per cent (1962) there is no doubt that a high level of malaria transmission still occurs on the island.

The general ecology is complicated by the peculiar location of the island. During the monsoon season, numbers of fishing boats arrive and stay for considerable periods on the protected west coast of the island. This means a transient population of several hundred arrive on the Pulau Tioman from the mainland each year. Thus the opportunities for bringing in new strains of malaria parasite is always present.

SIMIAN MALARIA ON PULAU TIOMAN

With the advent of Eyles' (1960) discovery that at least one of the monkey malarias in Malaya is transmissible to man via mosquito, the total ecology of primate malaria on Pulau Tioman becomes somewhat more complex. In order to determine the frequency with which this transmission of monkey malaria to man occurs in nature, a United States Public Health Service Team came to Malaya to carry on basic investigations into simian malaria in cooperation with the Malaria and Filariasis, and Entomology divisions of the Institute for Medical Research. In September, 1961, members of this team visited Pulau Tioman for general reconnaissance. Blood films from seven monkeys were made at this time. Five of these smears were positive from which *P. inui* and *P. knowlesi* have been definitely identified. It should be noted that one of the negatives was very young and one smear was made from an animal which had been dead for some hours and was therefore very difficult to read. In April, 1962, a second visit to the island by members of this research group was made and eight additional monkeys were examined all of which were positive. Once again *P. knowlesi* was isolated and two identifications of *Hepatocystis* sp. were made (Table 7).

TABLE 7

Monkey malaria on Pulau Tioman, 1961–62

No. Examined	No. Positive	% Positive
15	13	87

Aspects of the transmission of the monkey malarias on Pulau Tioman is much less clear than that for the human malaria. All of the monkeys on the island belong to a subspecies of the common mainland *Macaca fascicularis* or long-tailed macaque (*Macaca fascicularis laeta*). Although only 15 animals have been examined to date, 13 or 87 per cent have proven to be positive for haemosporidian parasites. Obviously a very high level of transmission is occurring on the island among these lower primates.

Unlike the human inhabitants of Pulau Tioman, the monkeys range the entire island from the tree and garden cultivation along the coast to the primary forest in more inland parts of the island (see Medway, this *Bulletin*, p. 16). The kampong

people complain of the deprivations of the monkeys in and around the village. As yet little specific information is available concerning the actual vectors of the monkey malarias. *A. maculatus* and *A. sundaicus* are quite susceptible in the laboratory to at least one species of monkey malaria from Malaya. There is no doubt that these animals do range through the *A. maculatus* and *A. sundaicus* infested areas on the island. However, there is considerable doubt as to whether these mosquitoes actually feed on monkeys.

A most interesting feature relative to the ecology of the simian malarias on the island is the isolation of *A. riparis* larvae from seepage pools in the hill forest. *A. riparis* belongs to the *A. leucosphyrus* group which includes three proven vectors of monkey malaria, *A. hackeri* (Wharton and Eyles, 1961), *A. balabacensis introlatus* (Eyles, et al., 1962) and *A. leucosphyrus* (Wharton et al., 1962) on the mainland. *A. riparis* has been found quite susceptible, in the laboratory, to one species of monkey malaria. *A. leucosphyrus* and the related *A. balabacensis* have both been caught biting man (Macdonald and Traub, 1960) and more recently have been attracted to monkey bait. *A. riparis* is common in Malayan forest but has never been caught on bait of any kind.

At the present time, little can be said relative to the ecology of the monkey malarias on the island. At least one proven vector is present and several other highly susceptible mosquitoes are relatively abundant in this area. The true potential for the transmission of these lower primate malarias to man is yet to be evaluated.

SUMMARY

The medical history of Pulau Tioman has been briefly reviewed. Malaria has been a prominent feature in the few recorded reports of investigations by various workers who have visited the island. Attempts have been made to control this disease which have included at least one program for massive, short-term administration of anti-malarial drugs. The incidence of malaria among the human inhabitants of the island was lowered after the more intensive campaigns but since these were of a more or less temporary nature, a high degree of transmission was quickly regained.

The nature of malaria in the human population is typical of other hyperendemic areas where virtually all of the children are infected very early in life with a high level of both morbidity and mortality. Adults frequently show enlarged spleens and occasionally patent parasitemias but rarely demonstrate a typical clinical response to the presence of the parasite.

Currently teams of sprayers visit the more populous areas of the island, but this does not usually occur more than once each year and the last malaria survey in 1962 gave a crude parasite rate of 19 per cent. There is no doubt that there is still a high level of transmission occurring on the island.

The status of malaria vectors on the island has also been reviewed. The human population is largely restricted to the narrow coastal plain which is wedged between the sea and steep hills which dominate the topography of the island. This area provides ideal breeding sites for *A. maculatus* and *A. sundaicus*. There seems to be little doubt that these two species are primarily responsible for the hyperendemic state of human malaria on the island.

Recent investigations into simian malarias on the island are reviewed. The monkey population is large and is confined to *Macaca fascicularis laeta*, a subspecies of the common long-tailed macaque found on the mainland. Blood films from 15 animals have been examined of which 13 were found to be positive for haemosporidian parasites. The ecology of simian malaria and its possible relationship to human malaria on Pulau Tioman is discussed.

ACKNOWLEDGEMENTS

Dr. Field's report is unpublished but appears in the files of the Institute for Medical Research, Kuala Lumpur. Reports of malaria surveys on Pulau Tioman since 1948 were also taken from the files of the Institute for Medical Research. Appreciation is also expressed to the Pahang State Health Department, Kuantan for making their records available and for providing much information concerning malaria control activities on Pulau Tioman.

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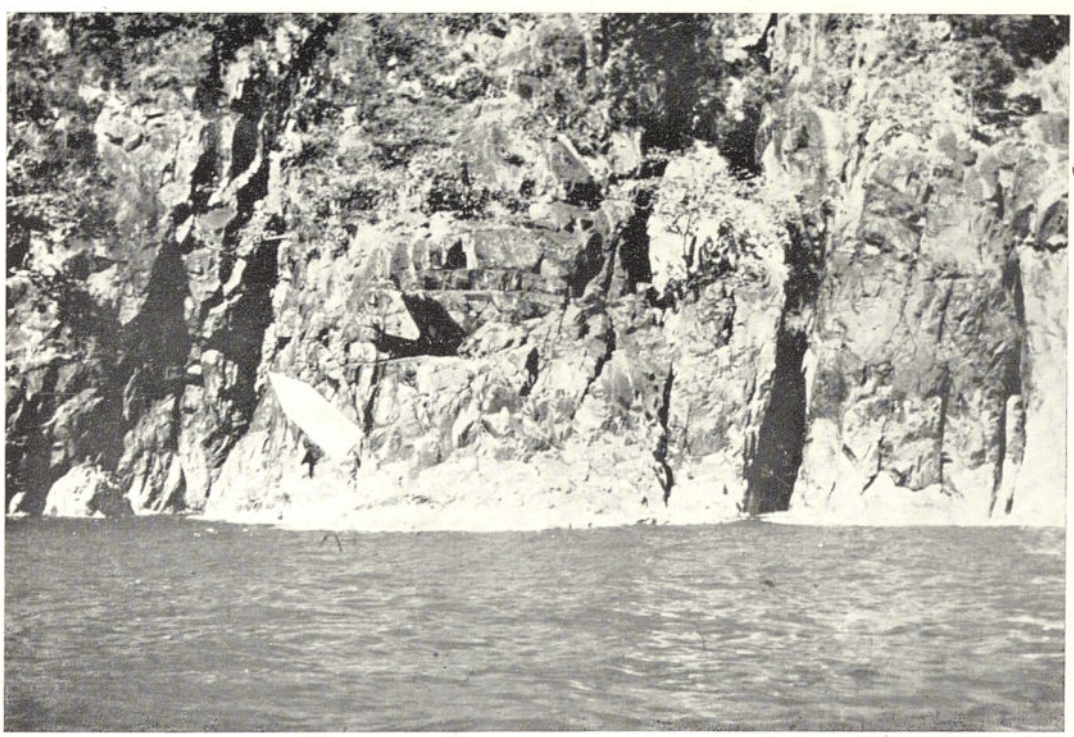
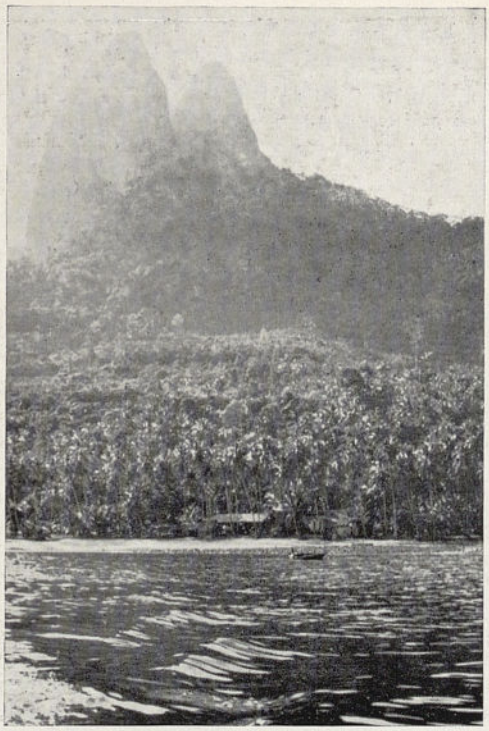
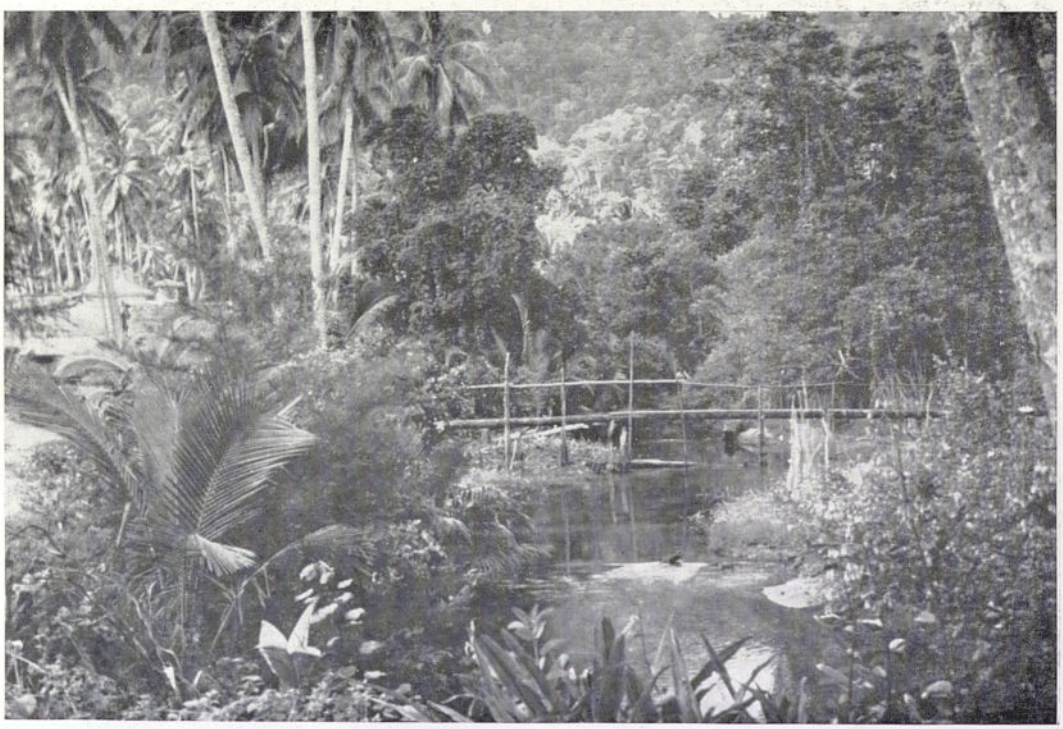


Above: The southern portion of Pulau Tioman, viewed from the southeast. *Below:* Cliffs of the east coast, north of Kg. Jgara. The arrow indicates a nest cave of *Collocalia fuciphaga.*



Above: Nenek-si-Mokut (2,400 ft.) near Kg. Mokut. *Below:* Cleared foreshore near Kg. Genting, showing exposed granitic boulders.

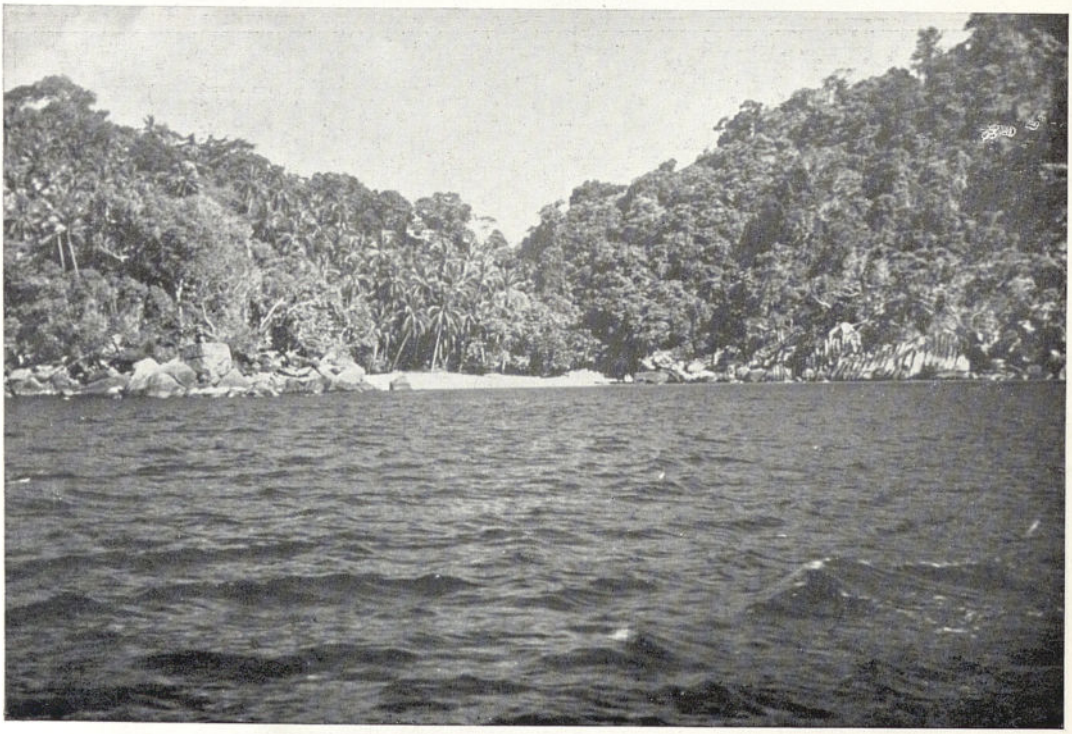


Above: Sungei Ayer Besar at 900 ft., near Camp II. *Below:* Final reach of the S. Ayer Besar running parallel to the sea, Kg. Tekek.

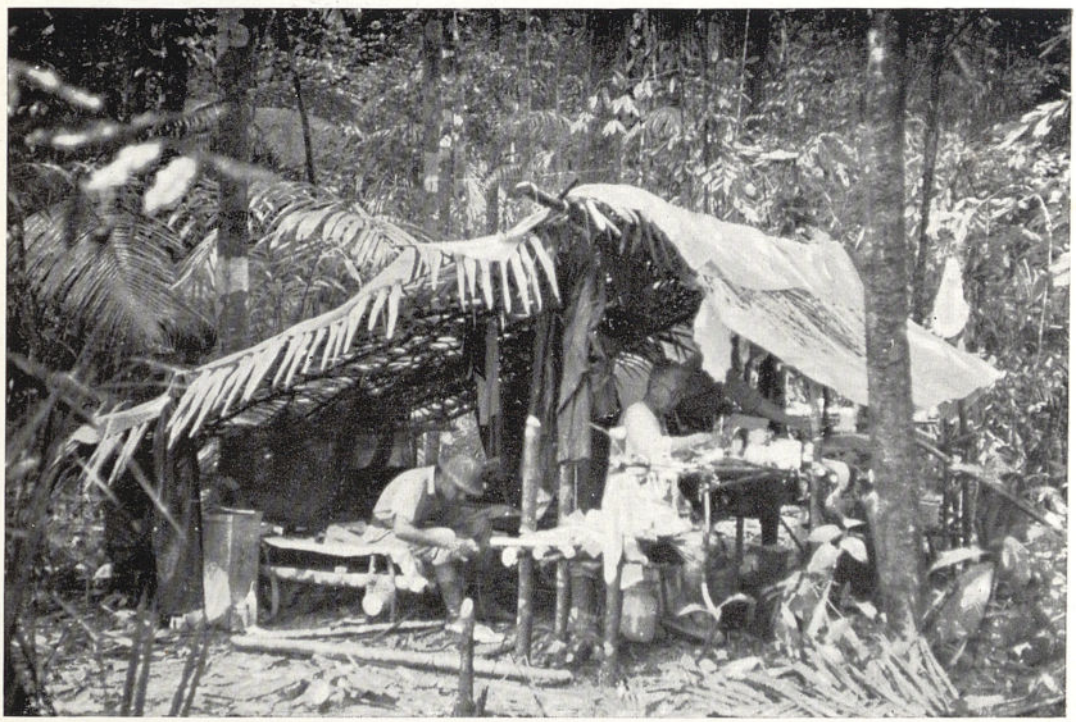
Above: Old coconut plantation at Kg. Tekek. *Below:* Heavy growth of *Lantana* sp. under coconut at Kg. Tekek.

Above: Old *ladang* at Kg. Tekek, showing successional banana plantation. *Below:* Carpet and lower storey vegetation in primary forest, on the Tekek-Juara track at about 500 ft.

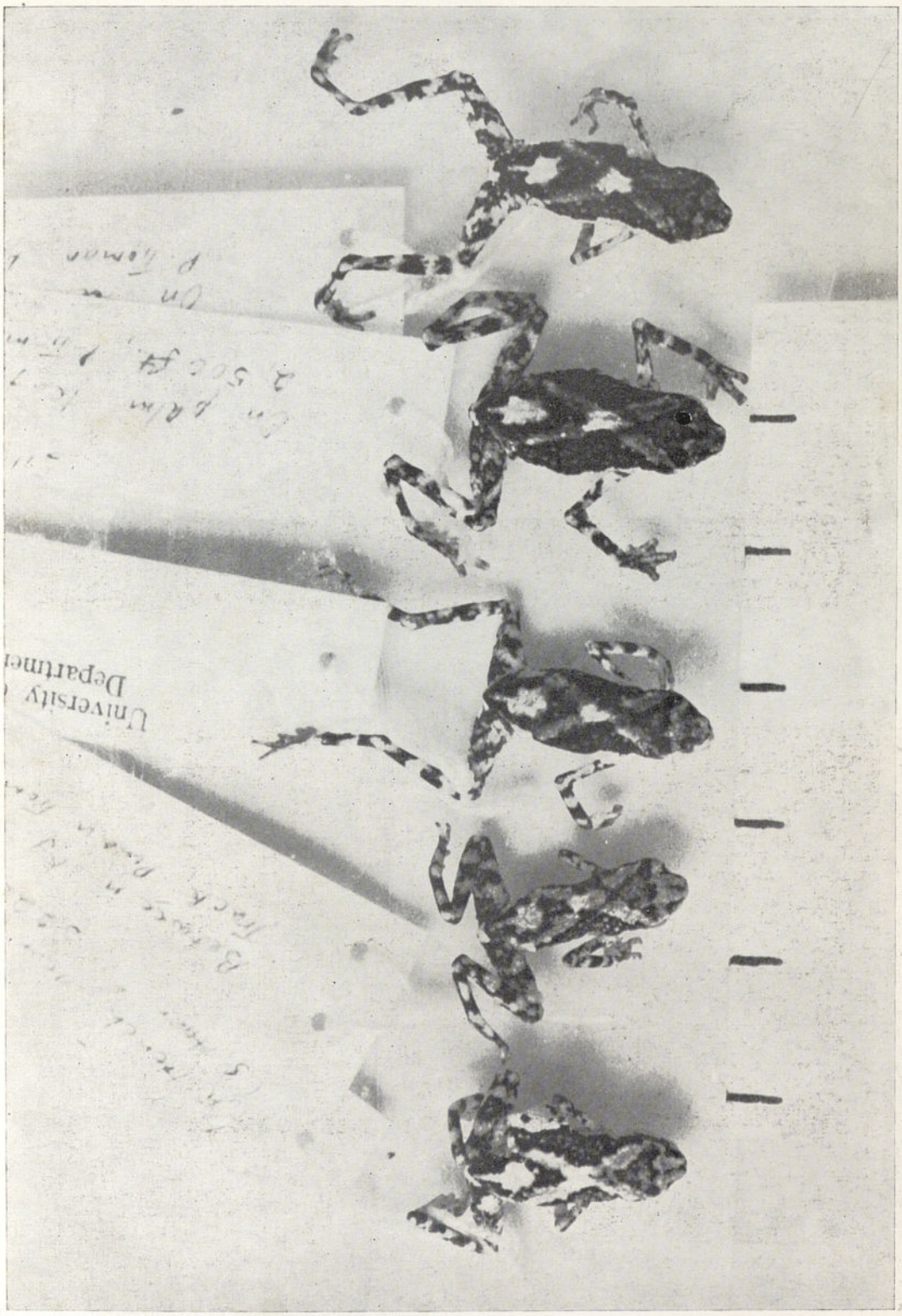
Above: Elfin forest at 3,200 ft. on Gn. Kajang (in mist). *Below:* Final slope vegetation at 3,350 ft. on Gn. Kajang.



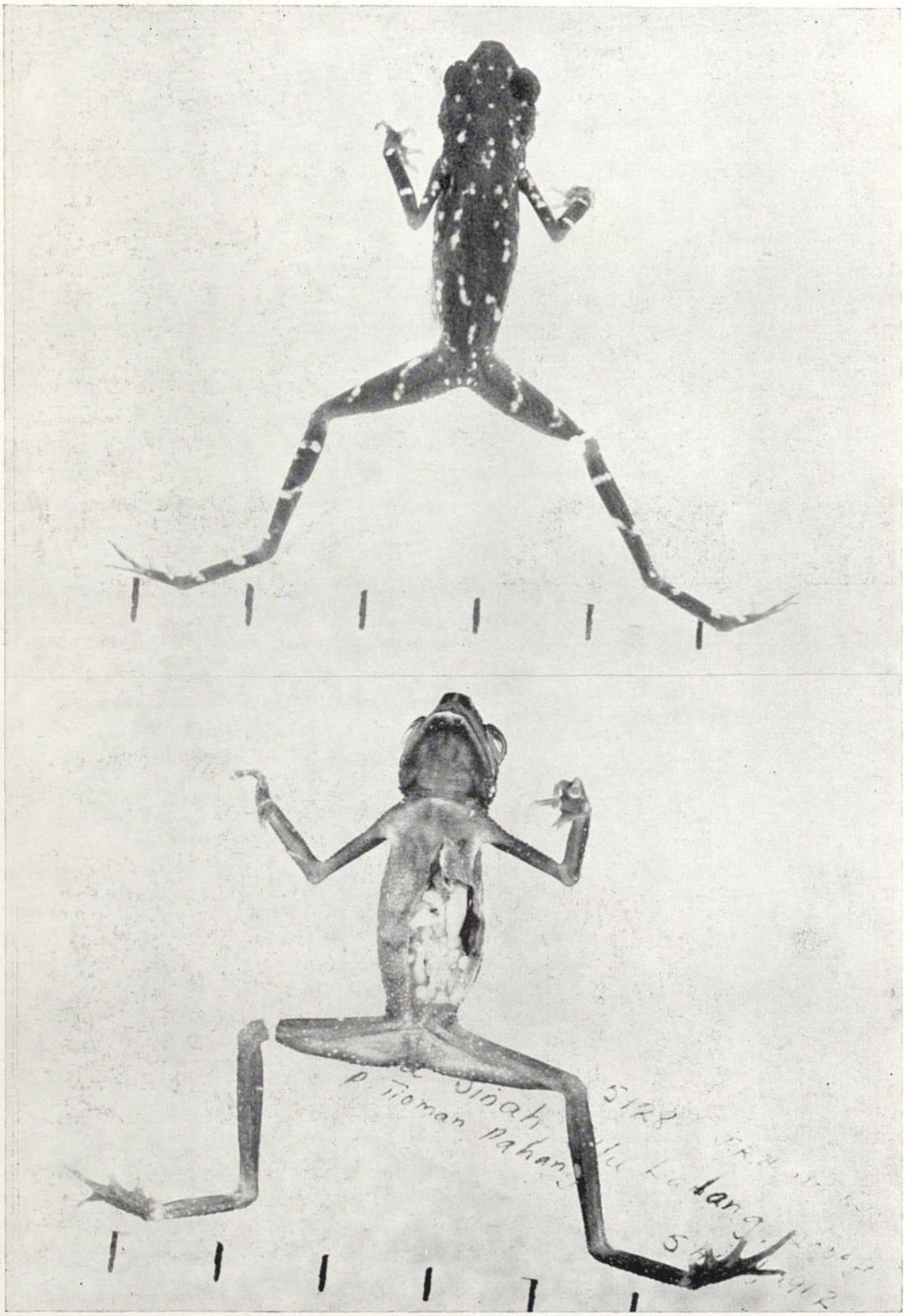
Above: Pulau Tulai from the southeast. *Below:* Bay on the southeast of P. Tulai.



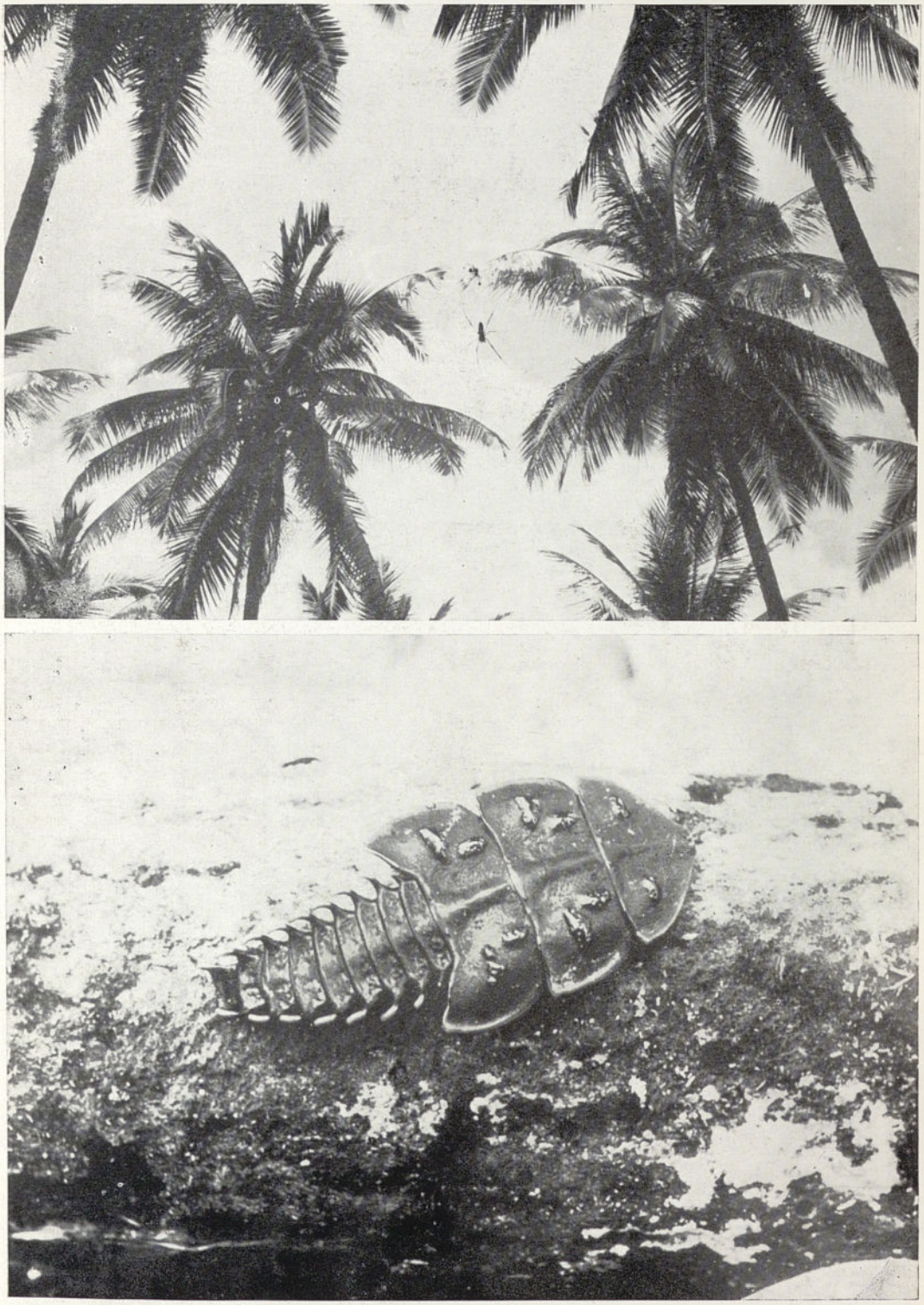
Above: The rest-house, Kg. Tekek (Camp I). *Below:* Camp II at about 1,000 ft. in primary forest.



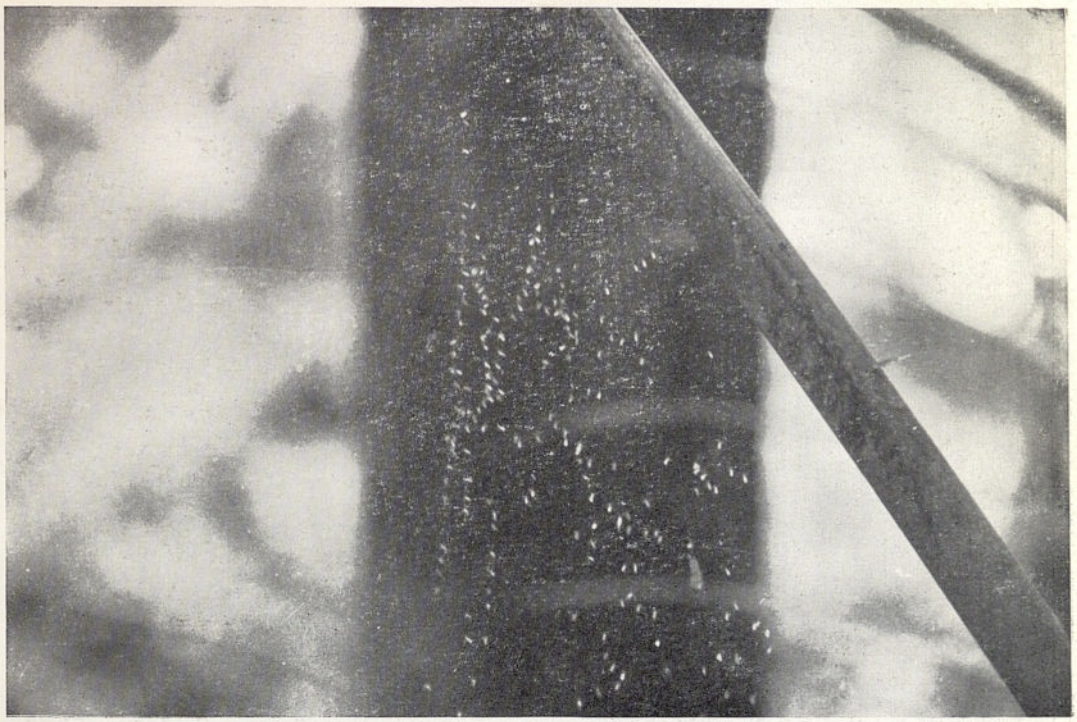
Pelophryne signata (Boul.) from Tioman, showing variation in dorsal pattern. (Scale marks at 1 cm. intervals).



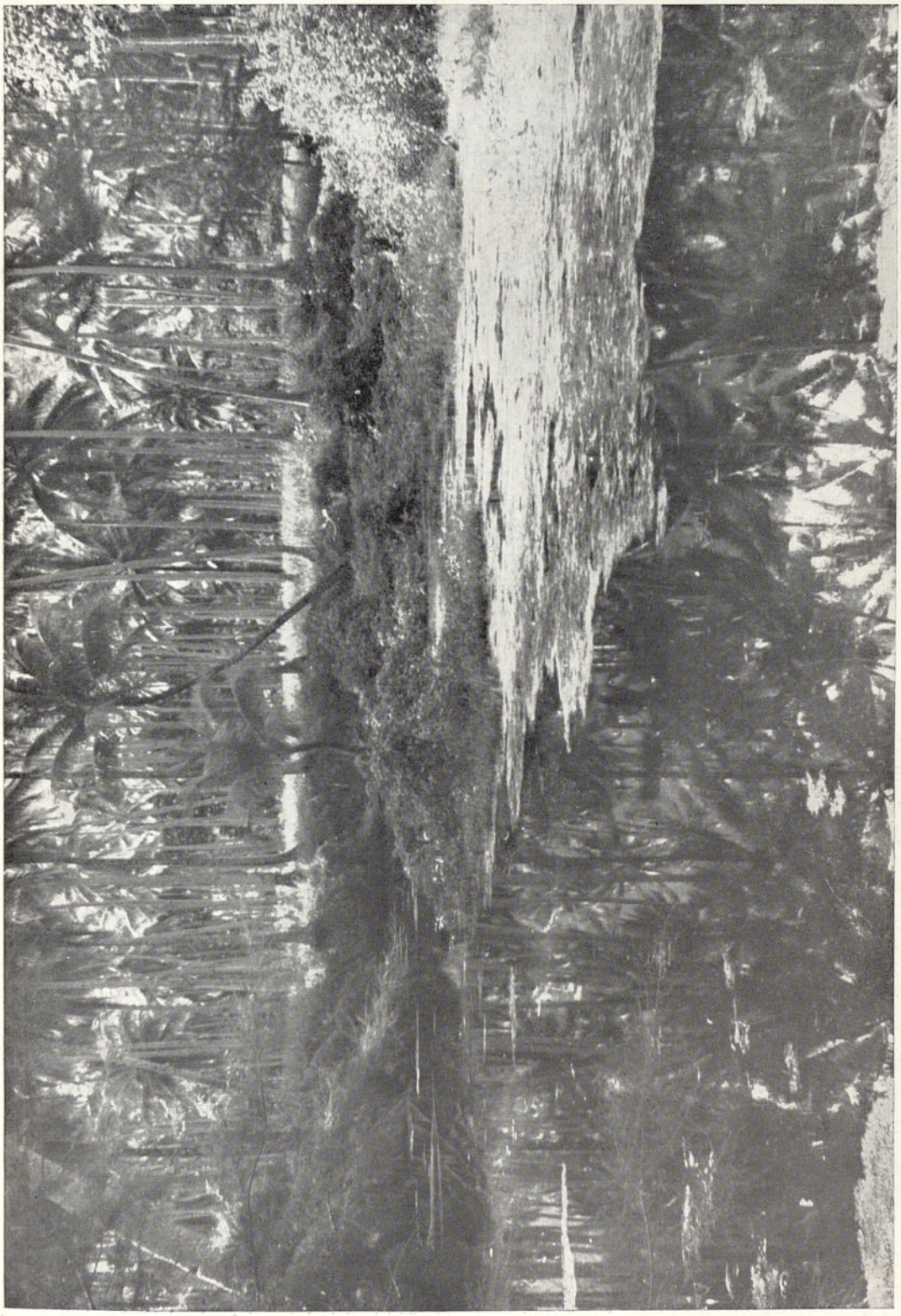
Above: Ansonia tiomanica sp. nov., adult male. *Below: Ansonia tiomanica,* ventral view of adult female, showing unpigmented eggs. (Scale marks at 1 cm. intervals).



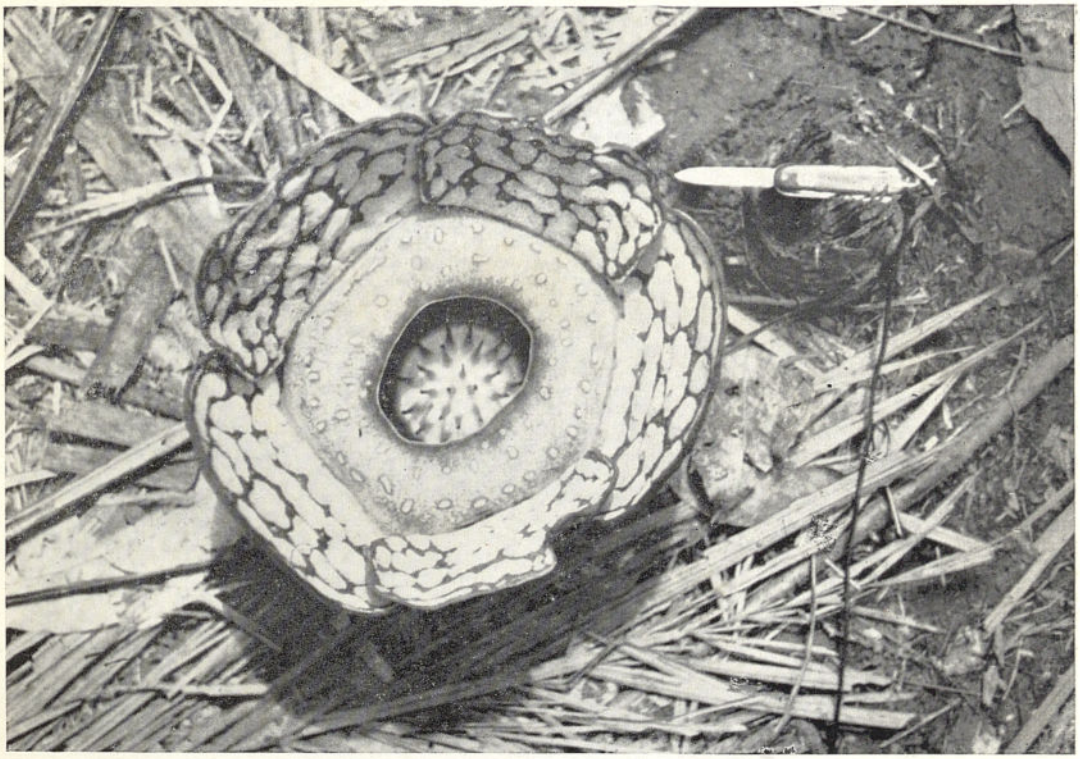
Above: Large Argiopid (Nephilinae) resting on web between palm trunks. *Below:* Trilobite larva (female Drilidae), on log.

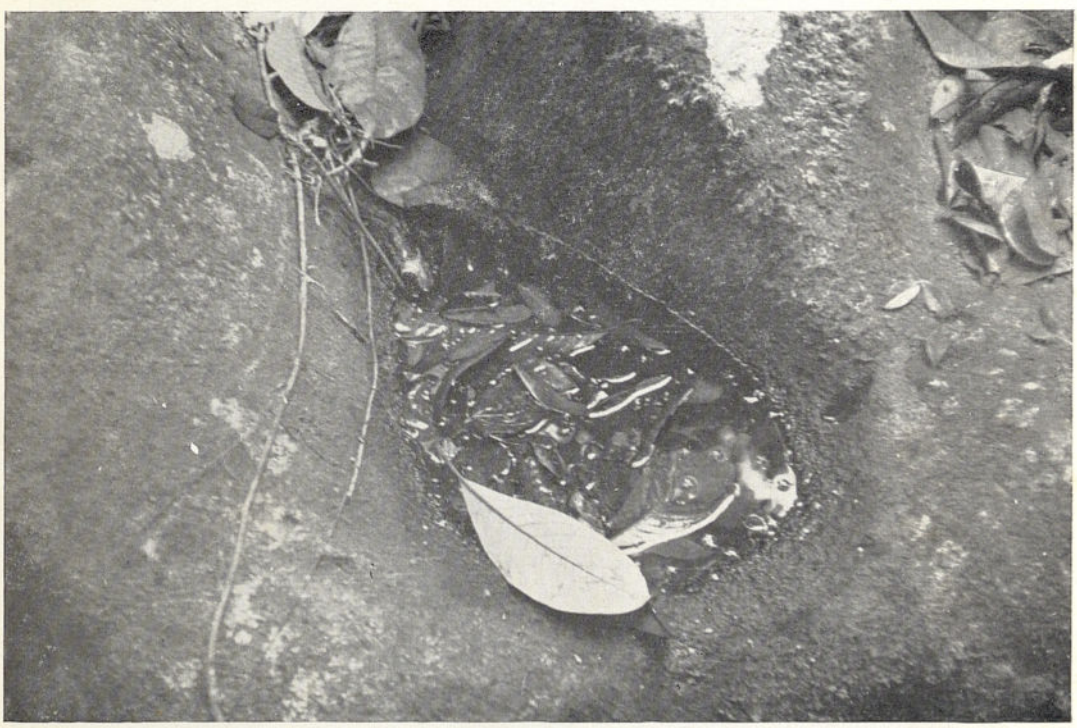


Above: Cecidomyids resting on a spider's web. *Below:* Boulders on the track between Tekek and Juara. (Height of photograph is about 6 ft.).



Fresh-water pond on coast near Tekek, with floating algal mat on which many *Rana erythraea* were caught.





Above: Flower of Rafflesia (after being cut from liane). *Below:* Small pool on rock above river level which was inhabited by Dytiscids and small Blattaria.